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Industry 4.0

the impact of horizontal integration on manufacturing business models and intellectual property strategies

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Industry 4.0: The Impact of Horizontal Integration on Manufacturing Business Models and Intellectual Property Strategies

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Abstract

The automotive manufacturing industry has been at the forefront of the so called fourth industrial revolution and the related digital transformation efforts which seek to implement digital technologies in individual businesses and to connect value chains in order to gain greater flexibility, reduce time to market and increase levels of productivity.

As manufacturing businesses digitalise knowledge and integrate their value chains, their business models are transformed, giving rise to a new paradigm with a range of emanating challenges and opportunities. This research is concerned with how the businesses models and intellectual property strategies in the automotive manufacturing value chain are affected by the implementation of Industry 4.0.

In this endeavour to clarify how manufacturing businesses are addressing this change in paradigm, this research conducted a literature review of Industry 4.0, business models and intellectual property strategies. As part of this study, the researcher collected and analysed empirical data from 31 interviews conducted with 27 senior managers, IP managers and engineers across 15 businesses in the UK automotive manufacturing industry.

Furthermore, 11 contractual agreements governing the relationships between these businesses were analysed and combined with the interviews into four case studies demonstrating the current and future appropriability regimes (defined for the purposes of this study as the dynamics and the means to protect knowledge and to secure return on investments made on innovation) in the context of the UK automotive manufacturing digital transformation.

The findings from this study suggest that the UK automotive manufacturing businesses must adapt their IP strategies in order to address the changes in the appropriability regime, tailoring their approach to value appropriation to suit a horizontally connected value chain where multiple complementary assets and protective mechanisms must be utilised in a strategic manner to secure return from investment in digitalisation.

This research also provides a number of contributions to knowledge and benefits for the organisations involved. A key contribution is a development of two new methods to evaluate the impact of this transformation on manufacturers and to support the mitigation of risk and opportunities, the Manufacturing Appropriability Regime Construct (MARC) and the I4.0 Business and IP Strategy Development Methodology (IBIPS).

Keywords: Fourth Industrial Revolution; Intellectual Property; Business Strategy; Intellectual Property Strategy; Manufacturing Appropriability Regimes.

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GLOSSARY & ABBREVIATIONS

Abbreviation	Term
I 4.0	Industry 4.0
HI	Horizontal Integration
VI	Vertical Integration
CPS	Cyber-Physical Systems
MBE	Model-Based Enterprise
MBD	Model-Based Definition
DT	Digital Twin
ET	Enabling Technologies
BM	Business Model
BMC	Business Model Canvas
BMO	Business Model Ontology
IP	Intellectual Property
IPR	Intellectual Property Rights
IPS	Intellectual Property Strategy
IPPM	Intellectual Property Protective Measures
(P)	Patents
©	Copyrights
(DR)	Design Rights
(™)	Trademarks
(TS)	Trade Secrets
BIP	Background IP
FIP	Foreground IP
SIP	Sideground IP
PIP	Postground IP
IA	Intangible Assets
TA	Tangible Assets
OI	Open Innovation
WIPO	World Intellectual Property Organization
IPO	UK Intellectual Property Office
WTO	World Trade Organization

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M. E. Kauffman, December 2019

1. CHAPTER 1 – THESIS INTRODUCTION

"Nothing has such power to broaden the mind as the ability to investigate systematically and truly all that comes under thy observation in life."

Marcus Aurelius Meditations 121 - 180 (2002) Book III, XI.

1.1. Introduction to the Research

This research is aimed at providing a novel and multidisciplinary analysis of Industry 4.0 (I4.0), business models (BMs) and intellectual property strategies (IPSs), exploring the new Industry 4.0 paradigm in manufacturing through the lenses of BM and IPS.

On a theoretical level, most studies concerning the adoption of I4.0 are limited to the examination of technologies related to I4.0 and the associated operational benefits. As such, there is a limited understanding regarding a business level (as opposed to just an operations level) account of the transformation across the manufacturing value chain which is affecting the manufacturers' relationships, particularly in terms of how they collaborate, share data and, most importantly, how these changes affect manufacturers, their business models and intellectual property strategies.

In an attempt to shed light on the impact of I4.0 on manufacturing BMs and IPSs, this study explores the ongoing transformation through an in-depth analysis of the implementation of I4.0 in the value chain of UK automotive manufacturing firms. In this particular sector, an exceptional effort is taking place to address the decade-long decrease in productivity through the implementation of digital systems which are designed to integrate the entire value chain (World Economic Forum 2019).

This unprecedented level of value chain integration is affecting all aspects of product development, manufacturing and commercialisation. Of particular interest in the context of this study, this transformation affects how businesses collaborate and the key processes utilised to control data and knowledge exchanges including the contractual processes, project management and IP management.

The data collected through interviews and contractual analysis was combined and analysed through four case studies, which exemplify the typical relationships found in the UK automotive manufacturing collaborations. Based on this data collection and analysis this research sought to address the gaps in the available literature in the fields of I4.0, BM and IPS, which are currently researched separately, even though in the business world these different subjects are closely connected and interdependent.

These fields of study and practice are of particular importance to the automotive manufacturing industry, which has experienced significant changes to all aspects of innovation and collaboration processes since the early 1990s, when the paradigm changed from solely in-house research and development (R&D), to collaborative R&D with key technology partners. Under the old paradigm, knowledge was produced in-house and maintained in a closed, controlled and local environment (World Intellectual Property Organisation 2011, :23). However, under the new paradigm the knowledge required to develop product and process technologies in an agile and effective manner almost invariably depends on collaborations across the manufacturing value chain.

An important driver for this change in manufacturing has been the increase in product and technology complexity, which influenced both, the product and technology innovation processes due to the challenges related the required capabilities in all technological areas of expertise required to innovate. Another key driver was the increased pace of technological development imposed by the customer demand for new products and a highly competitive environment, both contributing factors to reduction in time to bring new products to market.

As a result of these changes, manufacturing businesses began to open up the previously closed technology development processes and to increasingly seek complementary knowledge from external partners. This paradigm shift was made possible by the access to, and ability to make use of, digital communication platforms that enabled businesses to take full advantage of the opportunities created by networked technologies and the ability to exchange knowledge and information.

This study shows that I4.0 horizontal integration takes this change in manufacturing to a new level due to the increased speed of adoption of digital technologies and the transformation in the automotive manufacturing sector, resulting in further integration of manufacturing value chains with the objective of increasing productivity throughout the life cycle of products.

In this digitalised value chain environment, the level of knowledge and skills codified into digital systems and then exchanged between manufacturing businesses, their suppliers and customers is increasing exponentially, along with the risks and complexities emanating from these relationships.

This unprecedented level of knowledge codification and exchange in the manufacturing value chain results in numerous challenges and opportunities to how manufacturers create and capture value in their value chains. This in turn, increases the importance of understanding the impact of this change in paradigm in regard to manufacturing business models and intellectual property strategies (Jonda 2007; Kagermann, Wahlster and Helbig 2013; Loebbecke and Picot 2015).

This chapter describes the background and motivation that constitute the foundations of the research reported in this thesis. It then moves on to describe and formalise the research problem. Finally, the chapter provides a summary outline of the proposed approach to address the theoretical gaps and the practical challenges and opportunities faced by the automotive manufacturing businesses adopting I4.0 which will be analysed in detail in later chapters.

1.2. The Problem Context

During the course of the last five years, I4.0 has evolved from a very vague and misunderstood term to a concept widely discussed and recognised by industry, academia and the UK government. The concept encompasses the systematic digitalisation of individual businesses, as well as the connection of multiple businesses within and across industries encompassing an entire value chain (VC) in real time.

A value chain for the purposes of this study is defined with the same business management perspective as originally proposed by Porter (1985). In this way, a VC is a set of activities performed by various companies operating in a particular industry in order to create and deliver value to its customers. This concept of VC is based on the idea of processual perspective presenting the business as a system consisting of a number of subsystems each with its own inputs, value add processes and outputs all of which involve the acquisition and utilisation of tangible and intangible resources such as funds, equipment, materials, labour and knowledge (IfM 2013).

Paramount to the concept of I4.0 is the availability of all relevant information in real time through the entire VC, across all businesses and processes involved in value creation (product design and development, manufacturing planning, manufacturing operations and services), as well as, the ability to simulate alternative scenarios and derive the best decisions and possible value streams from data at all times.

As a result of I4.0, the UK automotive manufacturing value chain, which for the purposes of this research can be simply defined as “a complex set of social and technical resources that work together via relationships to create economic value in the form of knowledge, intelligence, a product (business), services or social good” (Allee 2002), is undergoing a phenomenal transformation that affects all manufacturing businesses involved.

The connection of various businesses across the value chain is likely to impact both existing and new relationships in the automotive manufacturing industry. These relationships are at the core of how manufacturers interact with their customer and suppliers and, more importantly, how they generate and capture value. On a practical level, as this study will show despite the aforementioned change in paradigm evident since the early 1990s, according to the Manufacturing Technologies Association (MTA) (The Manufacturer, 2017), each year millions of pounds in intellectual property rights are being neglected by the UK's manufacturing and engineering industries, because companies do not understand intellectual property within their businesses, designs, products and processes.

This issue increases in importance with the integration of the automotive manufacturing value chain, as manufacturers who are making substantial investments to innovate their businesses are exposed to potentially losing intangible assets to competitors due to their lack of IP awareness, which results in the failure to protect and appropriate value from their innovations. This issue was highlighted in a recent report by Intel Accelerate Industrial team (Intel 2019) which provides a comprehensive view of the digital transformation of the manufacturing sector through a study that interviewed over 400 manufacturing businesses showed that IP privacy, ownership and management is the second biggest threat that can affect return on investment from digital transformation according to manufacturers. In the IP challenges is second only to the challenges related to the technical skills gap.

Understanding this change in how value is generated and captured is paramount to this study, as will be discussed in sections 1.3 and 1.4 of this chapter. To address this particular aspect of the I4.0 transformation, this study utilised the literature of business models (BMs), which for the purposes of this research can be defined as "a representation of a firm's underlying core logic and strategic choices for creating and capturing value" (Shafer, Smith, and Linder 2005: 202), to explore how manufacturers' current and future BMs will be impacted by the horizontal digital integration of VCs, in conjunction with vertical integration and networked manufacturing systems.

This study proposes that by focusing on the manufacturer's value generation and capture, the researcher will be able to provide an insight into the most effective strategies for value protection utilising adequate IP strategies. This concern with value creation and capture is paramount. Despite the peer pressures in the manufacturing industry and large amounts of investment in the digitalisation of manufacturing which are associated with the hype regarding the economic benefits emanating from I4.0 evident in a variety of practitioner literature (McKinsey 2016; The Manufacturer 2017), there is still limited understanding as to how this value is to be realised, where this value will be generated and how it will be captured by manufacturing businesses.

This uncertainty concerning the economic benefit landscape can perhaps be attributed to the fact that much of the funding, research and focus so far has been placed on initiatives with the objective of advancements in operational, physical and technological aspects of I4.0. As argued by Brettel et al. (2014), there is a gap in the research and literature regarding the impact of I4.0 on current businesses and business models (i.e. how value is identified, generated, distributed and captured).

There are also gaps in the literature (to be discussed further in Chapter 2), regarding the understanding of the effects and the impact of such levels of connectivity and collaboration created by I4.0 on appropriation of value through IP protection in the manufacturing VC. One gap in particular, relating to the new level of horizontal integration, surrounds the impact on manufacturing BMs and IPSs in inter-organisation collaborations with increased exchange of data and knowledge in all forms throughout the product life cycle across the value chain.

In this context, it is argued by Kagermann, Wahlster and Helbig (2013) that I4.0 will have uncertain effects that will lead to a highly dynamic environment. The literature also shows that the disruptive nature of the combined power of technologies will lead to many challenges and opportunities regarding the legal aspects of a business. On the other hand, Kagermann, Wahlster and Helbig (2013) also propose that mastering and overcoming such challenges will lead to a competitive advantage in this new industrial paradigm.

In conclusion, the rationale for this research is to approach the phenomenon of I4.0 from a business perspective, viewed through the lenses of BMs in order to evaluate its impact on manufacturing businesses. This will enable the researcher to make a contribution to the BM and IPS literature. In addition, this research seeks to develop a method to support manufacturers in the identification of the sources of value, and how these sources can be analysed, generated and captured by manufacturers in this new industrial paradigm.

1.3. The Research Problem: The Impact of I4.0 on Value Appropriation

The UK government and UK automotive manufacturers are actively investing in new technologies to improve productivity and financial performance through the digitalisation of businesses and their entire value chains. This poses a very interesting set of challenges and opportunities to both theory and practice in the areas of business strategies and management, as well as IP management and value appropriation.

This research has been undertaken to understand and provide a source of support to manufacturers attempting to understand the challenges and opportunities relating to the impact of I4.0 on automotive manufacturers. The work has involved an exploration of approaches to evaluate the impact of the changes on BMs and the impact on the manufacturers' abilities to generate and capture value in the new interconnected VCs. In doing so, this study explores the critical question: What is the impact of Industry 4.0, and more specifically, of horizontal integration, on manufacturing BMs and their IPSs?

In this context the term Horizontal Integration is defined as *"Horizontal integration spans inter-organisational relationships between manufacturing businesses, suppliers, partners and customers, across the entire product or service life cycle." (Hermann et al. 2016; Kagermann et al. 2013)*. This presents level of integration across digitalised manufacturing businesses is a key issue due to the external exchange of data and IP which is now codified into digital systems which are accessible to third parties across the value chain and exposing sensitive information which may affect the manufacturer’s competitive advantage.

To answer the research question posed above, the thesis analyses the nature of the problems posed by the impact of the implementation of I4.0 on manufacturers’ BMs and IPSs, and proposes a range of mitigation actions to address both risks and opportunities. The main concern of this research is the management of information and data whose disclosure or unauthorised use by collaborators and partners across the horizontally integrated value chain can reduce the likelihood of manufacturers being able to appropriate value due to loss of IP and commercial advantage.

Furthermore, this study seeks to explore this transformation, and gather evidence from manufacturing businesses adopting digitalisation in the automotive manufacturing industry in order to contribute to theory in these areas, as well as to develop a set of practical recommendations to support manufacturers in their journeys towards I4.0.

In order to do so, a research overview figure was created to demonstrate the researcher’s approach to the research, highlight the three key areas of the study and explain the positioning of each of the key areas in relation to the central point of the research. The research overview, as well as the key areas of research, as shown in Figure 1, will be discussed below.

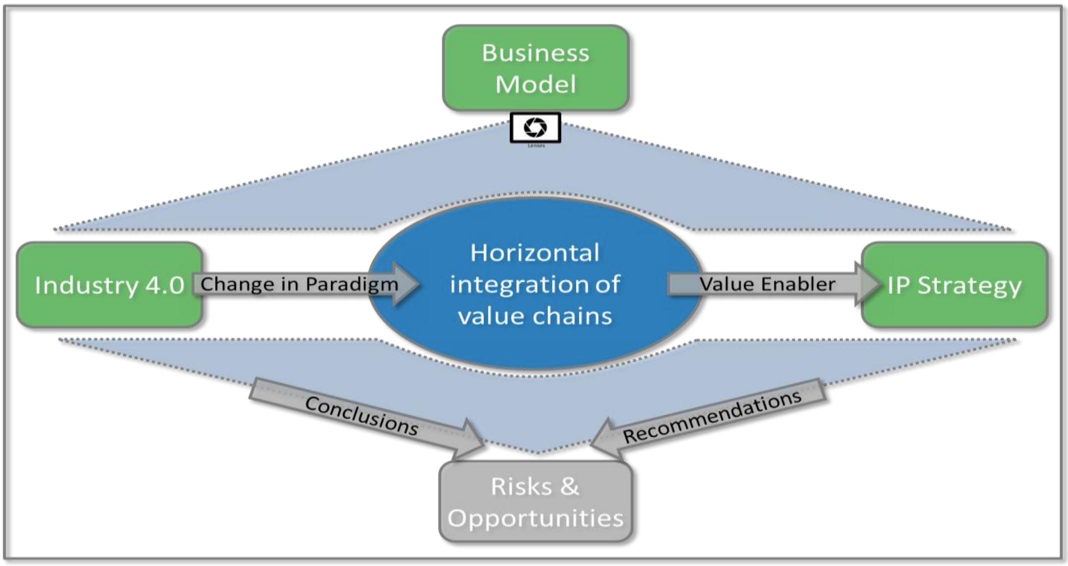

FIGURE 1 – RESEARCH OVERVIEW

I. Industry 4.0 – This represents the phenomenon leading to the change in the manufacturing industry paradigm. As will be discussed in the literature review, the term I4.0 is a reference to the fourth industrial revolution.

II. Horizontal integration of value chains – The next area of the framework represents the object of this research. Industry 4.0 is based on two concepts: vertical integration (e.g. the digitalisation of individual businesses), and horizontal integration (e.g. the integration of digitalised businesses across a given value chain).

III. Business models – This area represents the chosen lens via which the impact of the horizontal integration on manufacturing businesses will be explored. BM was selected due to its ability to demonstrate the core logic of how businesses relate to customers, suppliers and other partners in order to create and capture value by utilising its resources.

IV. Intellectual property strategies – This area represents the particular stance taken with regards to this research. IP strategies are recognised as a key value enabler. They are critical to the capacity of the business to appropriate value in inter-organisational relationships such as customer/supplier, collaborations and open innovation, all of which are likely to be present in horizontally integrated value chains.

V. Risks and opportunities – The final area represents the key objectives of this research, namely, to draw conclusions about the risks and opportunities emanating from the change in industrial paradigm, as well as to make recommendations as to how to address and mitigate such risks and opportunities.

It is argued that, for the automotive manufacturing industry to contribute to the UK's economic performance, academics and manufacturers must understand the change in paradigm instigated by I4.0. Armed with a good understanding of such a transformation, both academia and business can then evaluate the theoretical and practical impact on BMs and IPSs in order to maximise value to the UK economy.

The research aims to investigate the impact of I4.0 and the digitalisation of automotive manufacturing on current BMs, emerging BMs and the IPSs in order to address the following questions:

The Primary Research Question

> ***What is the impact of horizontal integration on current manufacturing business models and intellectual property strategies and how these can be changed to address risks and opportunities?***

The researcher is aware of the intrinsic challenges and complexities related to the primary research question, such as:

a) The meaning of Industry 4.0 and horizontal integration
b) The current manufacturing business models and the suitability of the available theories for business model evaluation in integrated value chains
c) The current manufacturing IP strategies and how they are impacted by this transformation.

A number of sub-questions have therefore been derived from the main research question, as set out below.

<u>The Research Sub-Questions</u>

Despite advances in I4.0 and an increasing number of publications in this area, there is still uncertainty regarding the definition of I4.0, particularly in relation to horizontal integration. The research uncovered that there was a clear gap in knowledge in this area and therefore a prime opportunity for contribution to theory and practice. As such the following sub-questions were defined:

What is Industry 4.0, and horizontal integration in the context of Industry 4.0?

There are many manufacturing BMs and even more BM tools available to document the current BMs for individual manufacturers. Nevertheless, the researcher acknowledges that there is much uncertainty in both theory and practice as to how I4.0 is going to affect the manufacturing value chain and as a consequence the manufacturers' BMs. Furthermore, the available BM tools are yet to be tested in this new environment. As such, the following sub-question was defined:

How is horizontal integration likely to impact current manufacturing business models?

As mentioned in the first sections of this chapter, despite increasing recognition of the importance of IP, automotive manufacturing businesses appear to lag behind other industries in terms of IPS for the appropriation of value from intangible assets. As such, the researcher acknowledges that there is scope for a contribution to theory and practice by exploring and documenting the current practices in terms of IPSs in the automotive manufacturing industry, as well as how these strategies will be affected by the adoption of I4.0. Therefore, the following sub-question was defined:

How is horizontal integration likely to impact manufacturing intellectual property strategies?

Recognising the limitations regarding IP practices in the manufacturing industry, the research emphasises the importance of contributing to theory and practice by providing a method to support manufacturing businesses to address risks and opportunities regarding their IP strategies and improve their positions in terms of value appropriation. The following sub-question was defined:

How can the current intellectual property strategies be adapted in order to address the risks and opportunities regarding value appropriation in the manufacturing value chain?

Answering these sub-questions will contribute directly to the understanding of the key areas of research as outlined in the Research Overview in Figure 1. It will also provide the foundation for answering the main research question. As such, the researcher will address each of these questions individually in this thesis, and in particular in the discussion chapter.

Nevertheless, it is recognised that due to the complexity of each area of this multidisciplinary project, some of these sub-questions may be given only a particular (specific to the UK automotive manufacturing industry) and partial answer, which provides a framework for further research.

1.4. The Research Aims and Objectives

Having defined the research problem and the research questions in the previous section, the aim of this research can be summarised as follows:

This study is aimed at researching and developing new knowledge, tools and methods to address the gap in theory and the practical challenges emanating by the implementation of I4.0 horizontal integration in the automotive manufacturing industry. These new knowledge, tools and methods will in turn support manufacturers

to understand the impact on their businesses, to identify and mitigate risks and to ensure that they are able to capture value originating from IP in the horizontally connected value chain.

In order to achieve this aim, the research has established the following main research objectives:

1. To critically assess the phenomenon of I4.0 horizontal integration in order to identify the potential impact on manufacturing businesses from a BM perspective (competitive advantages, value propositions, etc.).
2. To critically evaluate the impact of I4.0 horizontal integration on manufacturing BMs and IPSs, and collect empirical evidence to demonstrate the impact of I4.0 on horizontal integration in automotive manufacturers in the UK.
3. To develop and critically evaluate a flexible framework linking BMs to IPSs, in order to support manufacturing businesses to adapt their IPS to mitigate risks and capture value from opportunities in the context of I4.0.

1.5. The Thesis Overview

In this introductory chapter, the concept of I4.0 and the key areas and dynamics of this research were examined, providing a perspective on the impact of I4.0 on manufacturing BMs and IPSs. The chapter also points out that the change in paradigm triggered by I4.0, and its risks and opportunities, are not well understood as most of the 'hype' about the phenomena focuses on technical aspects (technology and engineering), rather than the socio-economic aspects (impact on businesses, society and the wider economy).

Chapter 2 then focuses on the literature review, providing a theoretical background and context for understanding the three key areas of this research, namely: I4.0, BMs and IPSs. Firstly, it provides an assessment of I4.0 and explores the key factors affecting, and likely to affect, manufacturing businesses and their business models.

Next, the BM literature in the context of I4.0 is critically assessed to review the changes taking place and how such changes are affecting individual businesses. Finally, this section draws together a number of distinct theories in order to generate a coherent view of how they explain and analyse the multiple perspectives on I4.0 horizontal integration.

The third and final theme assesses the implications of the horizontal integration of businesses in the value chain for IPS, which in this context is viewed as critical in linking business strategy, business models and value appropriation in the new inter-organisational relationships emanating from I4.0.

Through a review of the literature, a number of gaps have been identified. Of particular relevance to this research, these gaps are aligned to the research questions which were presented in the Introduction chapter (Section 1.3).

In Chapter 3, the researcher presents the research methodology utilising the Research Onion Model as proposed by Saunders, Lewis and Thornhill (2012). The chapter begins by presenting the philosophical stance and the research approach, strategy and design. This includes an explanation of the methods utilised, the shift in the researcher's perspectives and outlook during the research activities, and the reasoning for the choice of case study as a method for performing the qualitative analysis of in-depth interviews and secondary data.

In Chapter 4, the data collection activities are discussed, and the process and procedures utilised to practically collect the primary and secondary data in order to answer the research questions are explored in detail before presenting the raw data collected.

In Chapter 5, the researcher presents how the data analysis was performed via coding and explores the resulting themes. Furthermore, the chapter also introduces the four case studies used to group the data collected, and the Manufacturing Appropriability Regime Construct (MARC) which was used for an analysis of the value chain appropriability regime positions.

In Chapter 6, the researcher synthesises and integrates the empirical data and the literature review findings, and focuses on an exploration and evaluation of the five core themes emerging from the data analysis in order to answer the research questions. This chapter draws a parallel between the literature, empirical work and the research questions. The chapter closes with a presentation of the Business and IP Strategy Development Methodology (IBIPS) designed to support manufacturers in the alignment of business and IP strategies.

In Chapter 7, the researcher brings the project to a conclusion by providing an overview of the findings, and their contributions to theory and their practical implications. Finally, the chapter provides a review of the limitations of the study, and a potential future research agenda.

1.6. Chapter 1 Conclusion

Chapter 1 provided the introduction to this study and a ‘frame’ through which the reader can navigate the thesis. Chapter 2 focuses on the literature review for the key areas of research.

2. Chapter 2 - Literature Review

2.1. Introduction

The previous chapter provided an introduction to the research and exposed three key areas of research (I4.0, BMs and IPSs), which have been identified as the focus of this study. These areas have been constructed in part with reference to the practical basis for the research, but also partly with reference to the theoretical basis for the research, both of which will be explored in this chapter.

This chapter will begin with an exploration and assessment of the literature on I4.0, which in the context of this research represents the element of change to the manufacturing industry. This literature review will focus on a critical assessment of the I4.0 definitions, key concepts and most importantly the so-called horizontal integration (the integration of businesses across the value chain).

This section of the literature review will provide an assessment of industry-wide change affecting the manufacturing industry. It will also explore the key factors affecting it and the likely effects on manufacturing businesses and their business models. This will provide the macro-level lens through which to view the shift in industrial paradigm.

The next key area to be critically assessed is BMs. This theme will provide a micro-level lens (specific business perspective) through which to view the changes taking place and how they are affecting individual businesses. This study will utilise the concept of BMs as a method of analysis to critically assess the impact of the I4.0 implementation on manufacturing businesses, situating BMs not only as an abstract strategic tool but also as a practical/tactical tool for the identification of risks and opportunities.

The final section assesses the implications of horizontal integration of businesses in the manufacturing value chain on IPSs, which includes IP policies, procedures and processes, as well as informal IP protection methods such as secrecy, semi-informal protection methods such as contracts and formal protection methods such as patents.

IPS is identified as a critical enabler for the creation of the type of collaborative environment necessary to generate the horizontal integration of manufacturing businesses, as well as a method to mitigate risks and generate, secure and capture value.

Having introduced Chapter 2, attention will now turn to the methodology deployed in this literature review.

2.2. Literature Review Methodology

This literature review will provide an up-to-date overview and assessment of the key areas mentioned in the previous section: 1- Industry 4.0; 2- Business Models; and 3- Intellectual Property Strategies. The literature research design consisted of three main phases: i) The identification of relevant literature; ii) Literature preliminary analysis; and iii) Qualitative literature review.

Due to the popularity described in the introduction, and the exponential growth in publications in the area, the keyword search resulted in a significant number of publications. As such, a large amount of work was required in order to qualitatively select material to narrow down the scope of this literature review and to focus on the research questions as set out in Chapter 1.

2.2.1 The Relevant Literature

Industry 4.0

In order to identify I4.0 literature with potential to contribute to answering the particular questions posed in this study, the researcher extended the search to multiple databases, capturing multidisciplinary publications ranging from disciplines such as computer science and engineering, all the way to social sciences and law.

In this effort, the following publication databases were used in order to conduct the initial search for academic and practitioner publications: A- Scopus, B- EBSCOhost, C- ScienceDirect, and D-

OAlster. These sources were used in order to capture as many I4.0 publications as possible and provide contributions ranging from multiple areas where I4.0 is being researched and applied.

The initial search included the terms “Industry 4.0”, the English version covering publications in this language, and also “Industrie 4.0”, the German version of the term as such covering German publications. The search term focused on occurrences in the titles, abstracts and keywords of the publications. The results were then analysed for relevance by examining first titles and abstracts and then the full text; finally, the material deemed relevant in the context of this research was selected.

Business Model

In relation to BM literature, the researcher sought to utilise a single database in order to conduct the initial research for academic publications: A- EBSCOhost. The source also provided contributions ranging from a number of disciplines including information technology, business management, strategy, marketing, engineering, production, planning and logistics.

The initial search included the term “business model” in the titles and the keywords of publications with no time constraints. However, due to the large amount of publications on the topic of business models over the past 50 years, the search has been limited to a more recent and manageable timescale in alignment with the period of development of the key technologies enabling I4.0 implementation. As such, the time span from the search was set between January 2000 and December 2019.

Intellectual Property Strategy

The nature of the IPS literature is very diverse due to the complexity of the subject and the high economic impact. As such, IPS is researched from multiple perspective (economics, business strategy and law). In order to capture the literature with potential to support this study and to answer the research questions, the research has utilised multiple databases including publications from academics and practitioners in economics, business and law.

The following databases were used in order to conduct the initial research for publications: A- Westlaw, B- EBSCOhost, C- ScienceDirect. This initial search included the terms “Intellectual Property Strategy”, “Intellectual Property Management” and “Intellectual Property Protective Measures” in the titles, abstracts and keywords of publications.

2.2.2 Preliminary Analysis

Industry 4.0

The initial literature research resulted in a total of 479 publications with mentions of I4.0. A further seven articles have been identified in the form of practitioner reports. Out of these 486 papers, 127 were duplicate articles in different databases or in different languages. This resulted in a total of 353 papers which were screened for relevance by reading the title and abstract sections. Of these, 149 papers, whilst mentioning I4.0, were judged to be irrelevant to this study as they were simply focused on a particular technology, for example 3D printing or robotics. These papers were excluded resulting in 204 publications. Out of these, 197 were published in academic journals or conference proceedings and seven were practitioner publications. Following the full text review, another 53 publications were excluded due to contextual relevance, for example: a number of papers explored the information technology challenges behind a particular communication protocol to allow machine-to-machine communication. After this filtering process, the researcher had a total of 151 publications which were included in this review, as shown in Figure 2 below.

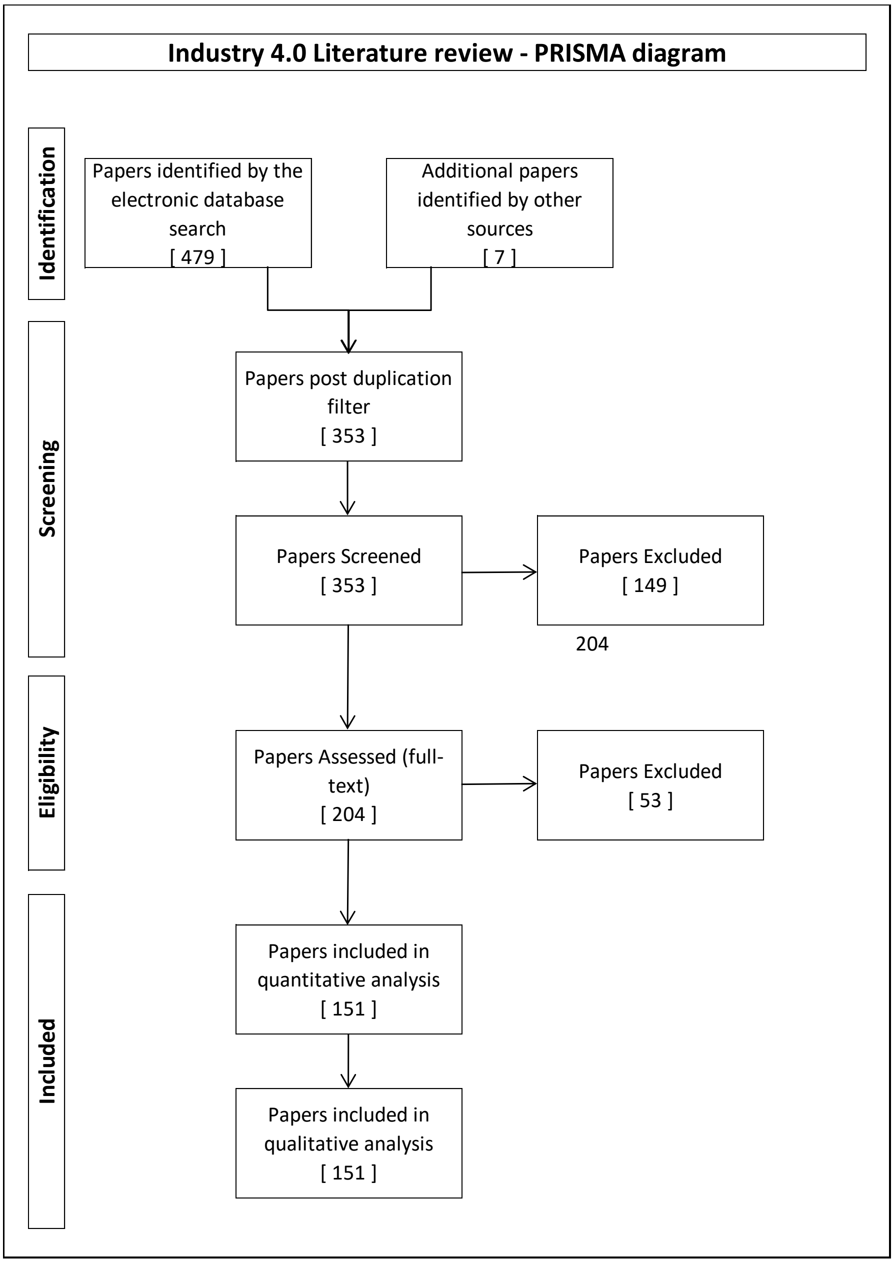

FIGURE 2 - PRISMA FLOW CHART FOR I4.0 LITERATURE

Business Model

The BM literature search resulted in 2093 articles, out of which 411 were duplicate articles in different databases or in different languages. This resulted in a total of 1682 papers which were screened for relevance by reading the title and abstract sections. 1415 papers were excluded based on lack of relevance, resulting in a final selection of 267 publications, all of which were published in academic journals or conference proceedings. Following the full text review, another 192 papers were excluded due to lack of relevance to this research and 75 publications were included in this review as shown in Figure 3 below.

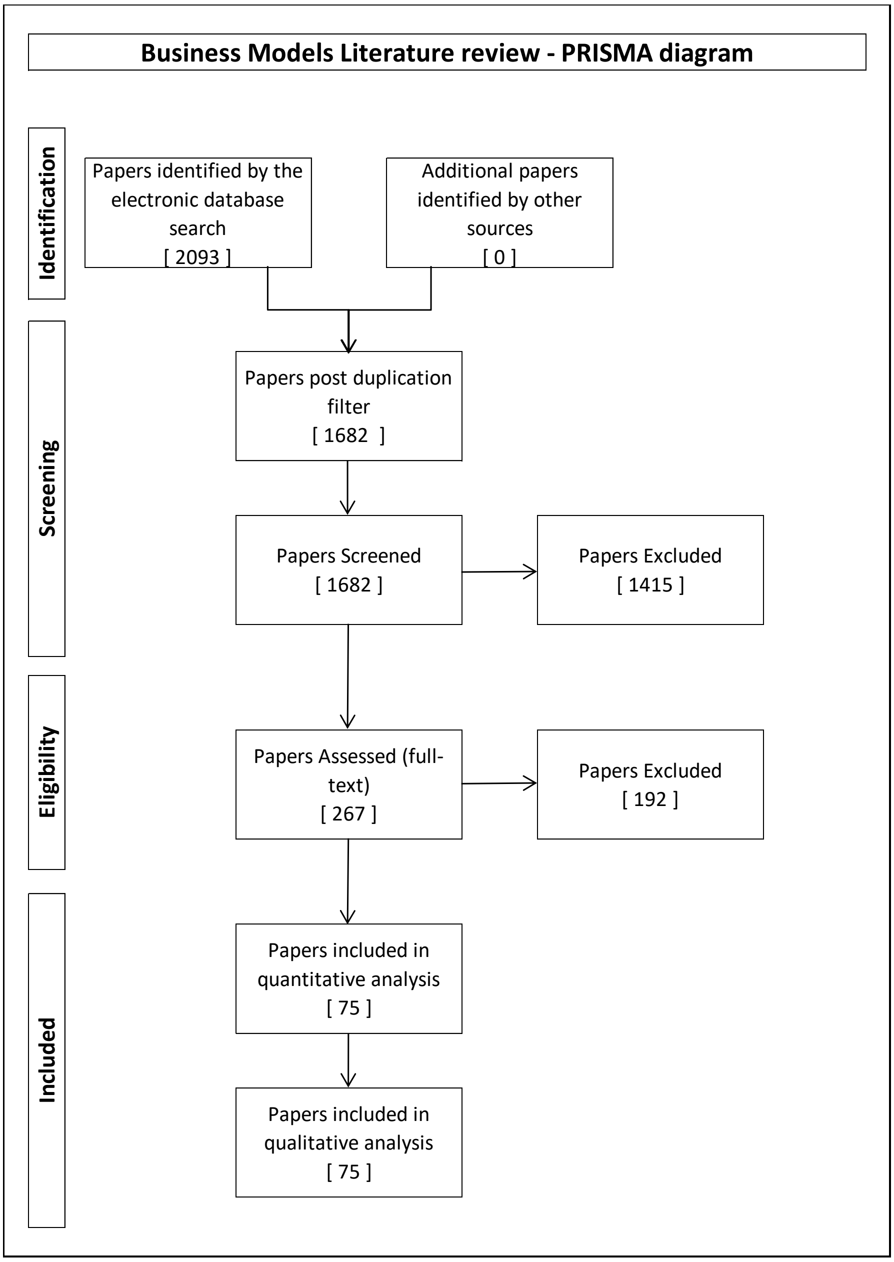

FIGURE 3 - PRISMA FLOW CHART FOR BM LITERATURE

Intellectual Property Strategy

The IPS literature research resulted in 803 articles, out of which 68 were duplicate articles in different databases or in different languages. This resulted in a total of 745 papers which were screened for relevance by reading the title and abstract sections. A total of 509 papers were excluded due to lack of relevance, resulting in a final selection of 236 publications, all of which were published in academic journals or conference proceedings. Following the full text review, a further 132 papers were excluded due to lack of relevance in the context of this research. Finally, 104 publications were included in this review, as shown in Figure 4 below.

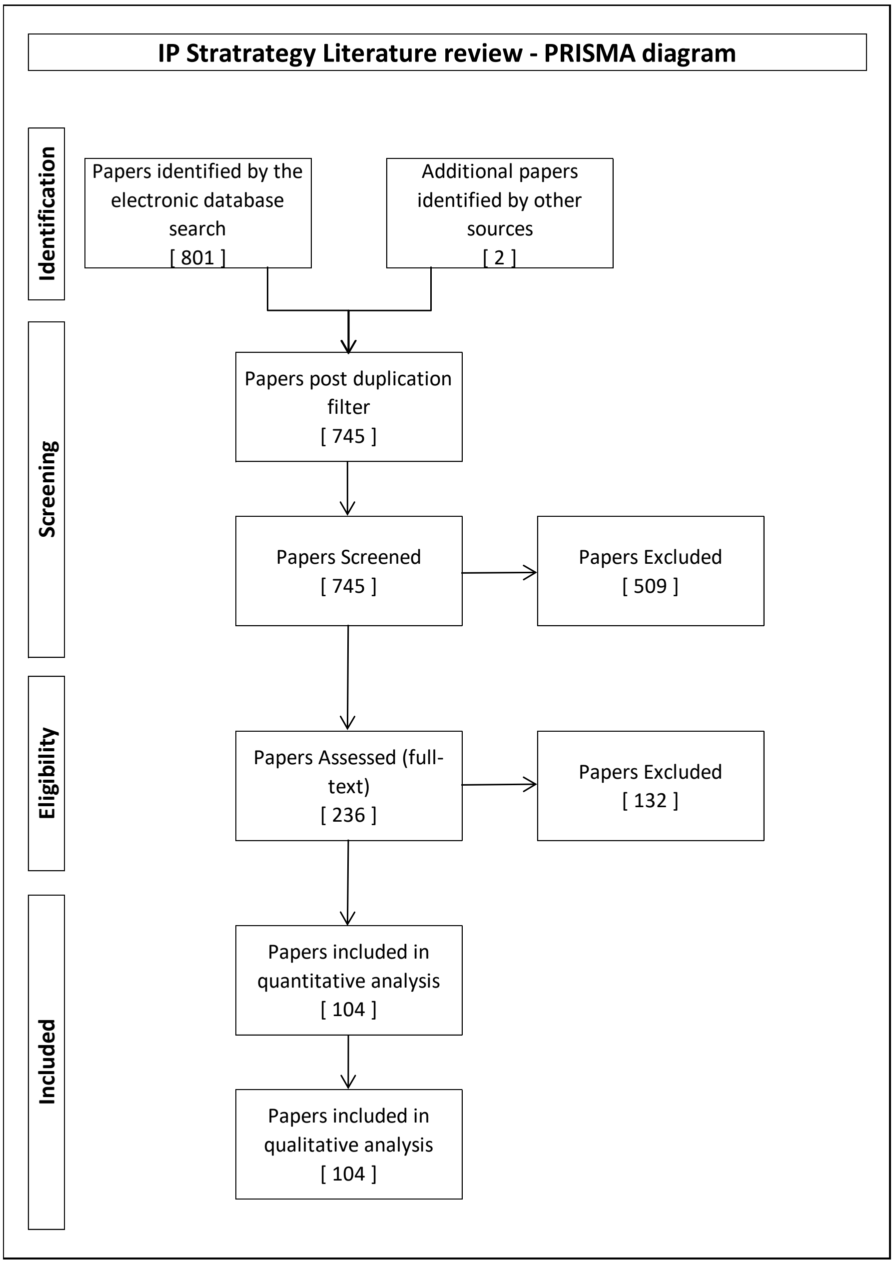

FIGURE 4 - PRISMA FLOW CHART FOR IPS LITERATURE

Having explored the literature review methodology and preliminary analysis, attention will now turn to the review of each of these areas in detail.

2.3. The Concept of Industry 4.0

2.3.1 Introduction

The phenomenon termed Industry 4.0 (I4.0) is currently one of the most discussed topics amongst practitioners, academics and worldwide governments (Drath and Horch 2014). This phenomenon, at least under the term I4.0, has its origins in the German government initiative called "Industrie 4.0", which formed part of the German industrial strategy and was originally coined in 2011 (Kagermann, Wahlster and Helbig 2013). Since the beginning of the decade, there were numerous academic and practitioner publications, industry studies and international conferences, all focusing on certain aspects of this new phenomenon (Bauernhansl, Schatz and Jager 2014).

The peculiar choice of using the word industry, and the number 4.0, was made to describe the fourth industrial revolution, which is currently underway and builds upon the previous three industrial revolutions.

The following figure describes the four industrial revolutions. The first, in the 18th century, introduced mechanical production facilities. The second, in the late 19th century, introduced electrification and the division of labour. The third industrial revolution took place in the 1970s with the introduction of programmable logic controllers using advanced electronics and information technology to improve automation of industrial processes. Finally, the fourth industrial revolution is taking place now, in the form of interconnected smart objects and the creation of cyber-physical systems (CPS) (Drath and Horch 2014).

The following figure shows a summary statement describing each of the industrial revolutions positioned over time.

Some materials have been removed from this thesis due to Third Party Copyright. Pages where material has been removed are clearly marked in the electronic version. The unabridged version of the thesis can be viewed at the Lanchester Library, Coventry University.

FIGURE 5 - THE INDUSTRIAL REVOLUTIONS (SIEMENS 2013)

At its core, I4.0 was born of an idea to integrate two other concepts, the Internet of Things (IOT) and the Internet of Services (IOS), to the manufacturing environment. According to Drath and Horch (2014), the popularity of the subject can be attributed to two key aspects.

Firstly, the estimated benefits and economic impact emanating from the industrial revolution is huge. Benefits in operational effectiveness and the enablement and development of new business models, products and services have the potential to change the entire industrial landscape (Kagermann, Wahlster and Helbig 2013; Kagermann et al. 2014; Lasi, Fettke and Kemper 2014; Kleibrink and Magro 2018; Telukdarie and Sishi 2019).

Secondly, it is arguable that, for the first time in history, an industrial revolution is predicted and experienced prior to and during the event, rather than being observed after it has developed over many years (Drath et al. 2014). This provides an opportunity for business and academia to assess the likely opportunities, risks and impacts of such a revolution on the future of industry.

The I4.0 vision is that the various businesses within the manufacturing industry will build global, borderless networks with connected machines, factories and distribution networks, which will be controlled efficiently and intelligently by sharing critical information to enable coordinated actions.

Thus, manufacturing will be composed of cyber-physical systems (CPS), which will form smart machines, smart factories, smart supply chains and smart industries (Kagermann, Wahlster and Helbig 2013; Gilchrist 2016).

Such integration at all levels has the potential to improve the industrial processes in the whole of manufacturing, through design, engineering, material usage, supply chains, and product life cycle management. This integration is equivalent to the I4.0 term ‘horizontal integration’ and is at the core of the vision.

Nonetheless, despite the popularity and focus given to I4.0, since its conception it has arguably struggled to have a clear definition. Both groups set up by the German government to promote and develop Industry 4.0 (Industrie 4.0 Working Group and Platform Industrie 4.0 Group) can only provide a description of their vision, the basic enabling technologies and a limited selection of scenarios and applications; they fail to provide a clear definition (Kagermann, Wahlster and Helbig 2013; Platform Industrie 4.0 2014).

Furthermore, even though the subject has, since its conception, moved up the agenda for universities, companies and governments, the definition provided by the myriad of publications in both academic and practitioner literature streams has varied massively and accomplished little with regard to clarifying its definition (Bauernhansl, Schatz and Jager 2014; Ruppenthal 2019; Castelo-Branco, Cruz-Jesus, and Oliveira 2019).

The publications emanating from German industry classify I4.0 into roughly four areas, namely: I) Horizontal integration through value networks (between a number of different factories); II) Vertical integration (within a single factory, also known as the smart factory); III) Life cycle management and end-to-end engineering; and IV) Human beings orchestrating the value stream.

Although the classification into these four areas improves our understanding of the scope of I4.0, it is a long way from providing a clear definition. Furthermore, it is evident from the literature review, to be discussed below, that most publications regarding I4.0 focus on areas II and III, whilst there is a clear gap in regard to areas I and IV.

It is argued that there is no single, agreed and generally accepted definition for the phenomenon (Bauer and Horvath 2015), which in turn affects the potential for meaningful theoretical study and research. Furthermore, it is also argued that there is a gap in the literature regarding the impact of horizontal integration on manufacturing business models and the intellectual property strategies in the face of this new level of inter-organisation integration.

This section of the literature review aims to provide an up-to-date overview of the I4.0 literature, in order to assess the available definitions of I4.0, as well as its main characteristics and design principles. Furthermore, this literature review will focus on a critical assessment of the literature regarding the impact of horizontal integration on businesses, business models and intellectual property strategies as they form the core of this research and are critical for the purposes of answering the research questions as set out in Chapter 1.

The following figure demonstrates the structure of the I4.0 section of this literature review.

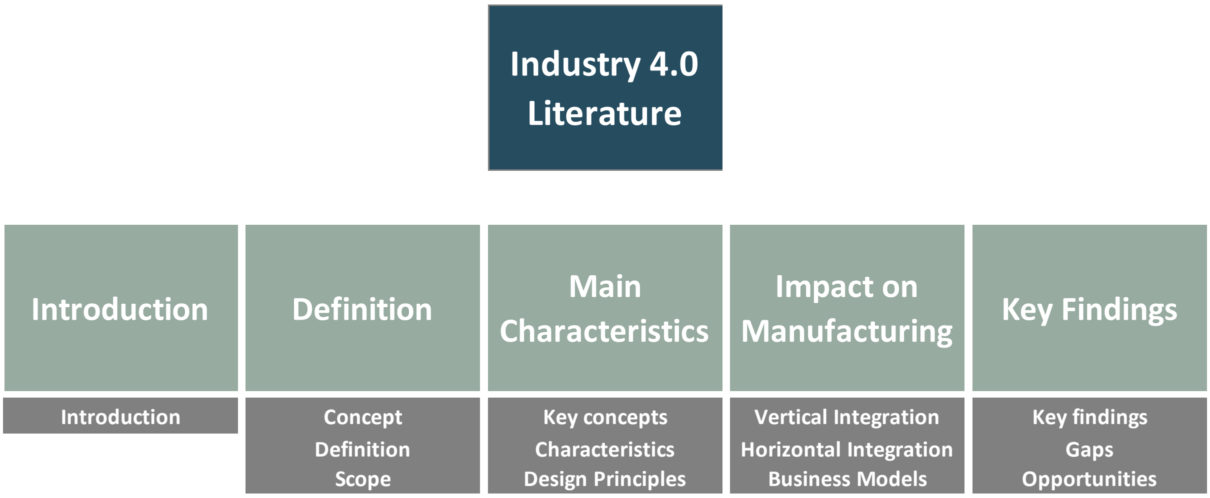

FIGURE 6 - I4.0 LITERATURE REVIEW STRUCTURE

2.3.2 Industry 4.0 Definitions

It is clear that industry, governments and academia have high expectations with regards to the phenomenon of Industry 4.0, which is seen as a driving force that will change the industrial paradigm and, according to Hermann, Pentek and Otto (2016: 39), will result in the following:

> ***"the economic impact of this industrial revolution is supposed to be huge, as Industrie 4.0 promises substantially increased operational effectiveness as well as the development of entirely new business models, services, and products"***.

Nonetheless, although many concepts, key elements and components have been identified, there is still a wide range of definitions at varying industry levels (product/individual business/individual industries/industry wide) being used to derive such expectations. This section will explore the range of definitions available in the literature.

The range of definitions is presented from various vantage points, and different levels of abstraction. For example, Faller and Feldmüller (2015) focus on a narrow definition with an information technology perspective on Industry 4.0, defining it as "IT integration of the production level with the planning level and further on to customers and suppliers" (Faller and Feldmüller 2015: 88). Other authors offer a wider view of Industry 4.0 as a bigger initiative, including changes in the market place and changing customer needs, organisational and hierarchical developments, and new working methods (Lasi, Fettke and Kemper 2014; Magruk 2016). The definition offered by Kirazli and Hormann (2015: 864) focused on a wider aspect and states that:

> ***"Industry 4.0 is the systematic development of an intelligent, real-time capable, horizontal and vertical networking of humans, objects and systems."***

On the other hand, Wang et al. (2016) also define Industry 4.0 in a narrower sense as the interconnecting of a production system, linking together various functions associated with production, such as logistics and warehousing, but arguably within a single business unit.

The Industry 4.0 definitions focusing primarily on IT transformation or an overhaul of manufacturing and associated business models also vary, arguably pointing at the fact that there is still a high degree of uncertainty as to what I4.0 really means and what are the likely implications for manufacturing businesses (Almada-Lobo, 2015). Some authors such as Oesterreich and Teuteberg (2016) offer a definition covering a number of factors and concepts:

> ***"multifaceted term comprising a variety of interdisciplinary concepts without a clear distinction"*** (Oesterreich and Teuteberg 2016: 122).

Some of these key concepts are also referred to in the literature as the technology enablers or key enablers and include big data, 3D printing, and robotics (Almada-Lobo 2015). The majority of definitions found in the literature focus on the operational impact on production and manufacturing processes. However, there are also references to the impact on the wider organisation of business, as in the definition offered by Schuh (2014) who identifies that the effects of Industry 4.0 will also impact indirect business functions.

On the other hand, the aforementioned "Industrie 4.0 Working Group" attempted to define I4.0 as:

> "***The concept encompasses the digitalisation of individual businesses and the connection of businesses, within and across industries encompassing an entire value network in real time***." Platform Industrie 4.0 (2013).

There are also many references to the I4.0 components, such as the integration of IOT into the manufacturing process (Kagermann, Wahlster and Helbig 2013), which allows physical 'things' and 'objects', such as sensors, actuators and smartphones, to interact with each other in a cooperative manner to reach common goals (Giusto, Morabito and Atzori 2010).

The author argues that this trend of defining I4.0 by relying on components or key elements is a prominent practice, evident in both the academic and practitioner literature. There are a number of terms used to identify I4.0. These include cyber-physical systems (CPS) (Monostori 2014), Factory of the Future (Jardim-Concalves, Romero and Grilo 2017) and Industrial Internet of Things (IIOT) (Arnold, Kiel and Voigt 2016). Ehret and z (2017) identifies four key component parts of I4.0, namely: information protocols and middleware, sensors, actuators, and information technology services such as artificial intelligence (AI) and big data analytics. On the other hand, Kirazli and Hormann (2015: 866) point out that:

> ***“The majority of the technologies required for implementation of Industry 4.0 are already available today. In many cases they are cross-sectional and basic technologies that have been in use for many years.”***

Furthermore, Magruk (2016) identifies six key determinants of Industry 4.0. These are:

i) Cyber-physical systems – which encompass the interconnection of systems and networks within the factory/organisation and with customers/suppliers;
ii) smart robots – which can interact with humans;
iii) big data, which encompasses the handling and analysis of the vast amount of data that can now be captured;
iv) connectivity through data exchange between humans, machines and systems;
v) energy efficiency and decentralisation, brought about by the emphasis on climate change; and
vi) virtual industrialisation or the replication of factories and products using process simulation and virtualisation.

Roblek, Mesko and Krapez (2016) identified three key points of progress for I4.0. These are digitisation of production through information systems, automation and manufacturing systems. Roblek and other authors also described the key characteristics of I4.0 as: digitisation and optimisation of production; automation and adaptation; value-added services; and automatic and integrated data exchange (Roblek, Mesko and Krapez 2016; Kovács and Kot 2017; Abbas 2018). All of these characteristics have a value and have a common purpose of adding value to manufacturers. It is also argued in some publications that the key to Industry 4.0 is the fusion of the physical and the virtual world (Kagermann et al. 2014). Such fusion is referred to as cyber-physical systems (CPS), defined below in section 2.2.4, which according to Lee et al. (2008: 363) provides:

"Integrations of computation and physical processes. Embedded computers and networks monitor and control the physical processes, usually with feedback loops where physical processes affect computations and vice versa."

The definition of I4.0 proposed by Hermann, Pentek and Otto (2016) identifies three key elements: the Internet of Things, cyber-physical systems, and smart factories. This definition is aligned with previous publications including Kagermann, Wahlster and Helbig (2013) where it is argued that the integration of IOT and CPS leads to the so-called "smart factories", a key feature of I4.0, nonetheless these smart factories cover only one I4.0 aspect, namely vertical integration.

Based on the above definitions, it is arguable that although there is a lack of a single definition for Industry 4.0, there is some consensus as to the key elements/components giving rise to the fourth industrial revolution as connecting people, things (machines/products) and data, resulting in new ways of organising industries, businesses and their processes.

There is arguably another dimension to the question of definition in the form of other concepts alias to "Industry 4.0" which, although very popular in Europe, is not so commonly used in other parts of the world (Lasi, Fettke and Kemper 2014). Thus, it is important to explore the comparable ideas that are usually associated or taken as interchangeable to Industry 4.0 in the Anglo-Saxon world. As an example, General Electric appears to promote a similar initiative under the name "Industrial Internet" (Evans and Annunziata 2012). The definition of "Industrial Internet" is presented in the Industrial Internet Consortium fact sheet published in 2012 as:

"*the integration of complex physical machinery and devices with networked sensors and software, used to predict, control and plan for better business and societal outcomes.*"

Such a definition appears to have a broader focus than I4.0 which emphasises the manufacturing industry processes and, as such, it could seem to refer to a subset of the Industrial Internet. Nonetheless, their components appear to be exactly the same, but deployed in a wider fashion, crossing industrial boundaries and extending to encompass the entire value network. Other similar concepts can be found under the terms “Integrated Industry” (Bürger and Tragl 2014), “Smart Industry”, or “Smart Manufacturing” (Dais 2014; Davis et al. 2012; Wiesmüller 2014).

In conclusion, the above literature review demonstrates a disagreement in the literature regarding the definition of I4.0. Nevertheless, the literature arguably agrees that I4.0 is not a new concept; it is essentially a new approach to manufacturing which makes use of the latest technological innovations to merge operational and information and communication technologies to share information and knowledge across the industry. The goal of such an approach is to manage the entire value chain, improving efficiencies and coming up with products and services that are of superior quality. This vision aims at higher flexibility and quality, but not at the expense of lower price.

With the above literature in mind, this chapter will progress with an analysis of the literature from two other perspectives, namely the main characteristics and design principles of I4.0; and the impact of I4.0 on manufacturing business models and intellectual property strategies.

2.3.3 Main Characteristics and Design Principles

Industry 4.0 Main Characteristics

The available literature presents a number of I4.0 concepts, amongst which three common components emerge, namely: 1- The Internet of Things (IOT); 2- cyber-physical systems; and 3- smart factories (Kagermann, Wahlster and Helbig 2013). Each of these components will be explored in turn in this section.

The Internet of Things (IOT)

The Internet of Things (IOT) refers to “**the main goal of making a computer sense information without the aid of human intervention**” (Gubbi et al. 2013: 1646). Gubbi identifies certain technologies associated with the Internet of Things, including RFID, sensor technology and smart connectivity, but with the added benefit of “***evolve[ing] into connecting everyday existing objects and embedding intelligence into our environment”*** (Gubbi et al. 2013: 1645).

Whilst there is no single definition for it, the Internet of Things refers to the interconnectivity of the physical and the virtual world, and applies to a variety of industries already, including transport, production systems and utilities (Wortmann and Fluchter 2015). A number of challenges can be identified at a strategic, operational and technological level. Some strategic challenges result from the need for new business models and strategies to adapt to the new requirements of I4.0, whilst operationally, new processes and tools may need to be employed to align with the IOT offerings. Technologically, the IOT will require increased integration of technologies, as well as further considerations around security, scalability and standardisation.

Cyber-Physical Systems (CPS)

Cyber-physical systems (CPS) refers to the integration between machines, and across the value chain (Monostori 2014). CPS is also described as the interconnectivity between physical elements and computational elements (Herterich et al. 2015). In contrast to the IOT, “CPSs present a higher combination and coordination between physical and computational elements” (Jardim-Concalves, Romero and Grilo 2017, p.7).

This connection and combination of objects over the IOT will demand the management of vast amounts of data through the value chain (National Academy of Science and Engineering, 2015). This connectivity has been argued as the most important and also the most complex characteristic of I4.0 (Xie et al. 2016; Cappellin et al. 2017; Tao et al. 2019).

Smart Factories

Finally, smart factories represent the integration of the two concepts of CPS and IOT (Hermann, Pentek and Otto 2016). The smart factory is depicted as the central point of Industry 4.0, equipped with the latest digitised solutions, and interacting with all stakeholders across the value chain (Magruk 2016). It is able to cater for mass customisation requirements of customers, enabling flexible mass manufacturing through the combination of smart machines, smart objects and the IOT (Wang et al. 2016).

As can be seen from these three common concepts, the I4.0 vision is heavily based on the integration of factories as well as the value chain via inter-organisational relationships. Kagermann, Wahlster and Helbig (2013) position these three concepts as enablers to achieve the four key characteristics which are located at the centre of the I4.0 vision.

I - The **vertical integration** is the networking of smart factories, smart products and other smart production systems. The essence of vertical networking stems from the use of cyber-physical systems (CPSs), which allow factories and manufacturing plants to react quickly and appropriately to variables such as demand levels, stock levels, machine defects and unforeseen delays (Hermann, Pentek and Otto 2016; Kagermann, Wahlster and Helbig 2013).

II - The **horizontal integration** through value chain networks which will facilitate the setup and maintenance of localised networks to create and add value. Such integration spans inter-organisational relationships between manufacturing businesses, suppliers, partners and customers, across the entire product or service life cycle. Furthermore, it can also include the integration of current and new business models at a local or international level (Hermann, Pentek and Otto 2016; Kagermann, Wahlster and Helbig 2013; Müller 2019).

III - **End-to-End Engineering** across the entire value chain, where the complete life cycle of the product is traced from concept to obsolescence, also known as “from cradle to grave(Hermann, Pentek and Otto 2016; Kagermann, Wahlster and Helbig 2013)..

IV - **Acceleration of manufacturing** operations via the utilisation of technologies that are new to the manufacturing industry, most of which are neither innovative nor expensive, and most of them already exist (Hermann, Pentek and Otto 2016; Kagermann, Wahlster and Helbig 2013).

The above three components and four characteristics arguably help to understand the basic tenets of I4.0, but they still fall short of a clear definition that enables academics or practitioners to explore the implications on I4.0 on manufacturing businesses and the value chain. Having discussed the key concepts and characteristics present in the available literature, attention will now turn to the literature regarding the key design principles of I4.0.

Industry 4.0 design principles

Hermann, Pentek and Otto (2016) provided a different approach to analyse the phenomenon of I4.0; via a quantitative text analysis, their study identified four design principles emanating from the available literature up to 2017.

The four design principles or key principles are the following: I) Interconnection; II) Information transparency; III) Decentralised decisions; and IV) Technical assistance. The authors defended this approach by arguing that it will support further development of both practice and research in regard to Industry 4.0. As these key design principles are aligned with the design principles emanating from the wider literature (Zuehlke 2010; Giusto, Morabito and Atzori 2010; Hermann, Pentek and Otto 2016), this section will follow the same structure in order to draw parallels from other articles in order to explore each principle in turn.

I - Interconnectivity

The first key principle of Industry 4.0 according to the literature analysis provided by Hermann, Pentek and Otto (2016) is interconnectivity. This principle aims to create the Industrial Internet of Things (IIOT) by connecting people, machines, devices and sensors. These interconnected objects and people are able to share information which is used to form the basis of a collaborative system of resources aimed at achieving a common goal (Giusto, Morabito and Atzori 2010). Furthermore, it is argued by Schuh et al. (2013) that there are three types of collaboration in this system, namely: a- human-human, b- human-machine, and c- machine-machine. Zuehlke (2010) argues that the establishment of common communication standards is paramount in order to enable the interconnection at such scale.

II - Information transparency

The second key design principle is information transparency. Higher levels of information transparency are arguably a by-product of the increased number of things connected over the IIOT (Lasi, Fettke and Kemper 2014).

This principle rests on the premise that I4.0 will enable the fusion of the physical and virtual worlds, resulting in new levels of aggregated information and processing capability (e.g. parallel simulation), leading to new insight. This virtual copy of the physical world, also known as the "digital twin" or "Cyber Physical Systems" (CPS), will be able to constantly analyse real-time end-to-end performance and simulate various outcomes (Kagermann et al. 2015).

It is argued that in order to meaningfully analyse the physical world, raw sensor data must be aggregated to higher-value context information to be interpreted in the digital world. This in turn creates true transparency (a real-time, end-to-end view of all relevant data for a manufacturing business), which combined with data analytics accessible to all participants will lead to better decision-making utilising all relevant and real-time information (Bauernhansl, Schatz and Jager 2014).

III - Decentralised decisions

It is argued that the third key principle, namely decentralised decisions, is a by-product of CPSs as their embedded algorithms, computers, sensors and actors allowing for monitoring and controlling the physical world, either semi-autonomously or fully autonomously (Lee 2008). These decentralised decisions are enabled via the interconnection of objects and people, and by the transparency of information emanating from a value stream extending from end to end of the value chain. The concept of decentralised decisions, for the purposes of better decision-making and improved productivity, was proposed in 1999 by Malone (1999). Furthermore, Hompel and Otto (2014) argues that IIOT participants will be able to perform their tasks autonomously and deal with exceptional cases on an ‘as and when’ basis where decisions need to be delegated to the management team.

IV - Technical assistance

The final key principle emanating from the literature is technical assistance. It is argued that due to the production complexity levels emanating from CPS and decentralised decision systems, humans will require support from an assistance system, which will aggregate data and help with the visualisation and interpretation of information, ensuring that humans can make informed decisions (Gorecky et al. 2014).

The use of smartphones and tablets already plays a central role in connecting people in society and making vast amounts of data available at everyone’s fingertips. The use of wearables is expected to further expand this method of connectivity and data exchange to drive decision-making (Williamson et al. 2015).

In conclusion, as with the I4.0 key characteristics, these key design principles arguably emphasise wider manufacturing integration, both in individual businesses and across the value chain via inter-organisational relationships. As such, there is a consensus in regard to the I4.0 vision to “integrate horizontal and vertical channels”.

Thus, it is argued that a combination of I4.0 key characteristics and principles can improve the comprehension of the phenomenon and lead to a better level of understanding of the concept. This could aid the analysis of the impact of I4.0 on manufacturing business models and manufacturing intellectual property strategies.

Having explored the literature from the perspective of the I4.0 characteristics and design principles, attention will now turn to the literature regarding the impact of I4.0 on manufacturing businesses.

2.3.4 The I4.0 Impact on Manufacturing Businesses

As mentioned in section 2.2.1, the I4.0 literature is more prevalent in the technical areas of vertical integration and end-to-end engineering, whilst the horizontal integration and value stream orchestration is less developed (Caputo, Marzi and Pellegrini 2016). It is argued that the focus on the technological effects, rather than business and value stream wide effects, of new developments within industry is not unusual and has occurred in other transformational initiatives, which were initially driven by the technical effects they had.

For example, this was evident in widely adopted manufacturing initiatives such as Lean and Six Sigma, which were implemented despite the lack of empirical evidence or understanding of their wider impact on business performance (Gutiérrez, Montes and Sanchez 2009). Furthermore, Dahlgaard-Park et al. (2005) also confirm this by identifying that most of the focus on Six Sigma lies on the tools necessary to implement the new initiative, with a lesser focus placed on the business implications.

In the context of I4.0, Lasi, Fettke and Kemper (2014) have argued that industries must recognise the organisational changes that will result as the businesses implement new business models and ways of working resulting from the technological developments related to I4.0. Nonetheless, Caputo, Marzi and Pellegrini (2016) argue that the literature on I4.0 tends to focus primarily on the technological aspects, as opposed to the wider organisational implications. In the same vein, Roblek, Mesko and Krapez (2016) state that organisations have yet to recognise the changes required by I4.0 and the factors which triggered I4.0. Nevertheless, the author mainly focuses on the technological changes brought about by I4.0, as opposed to any business implications.

Some business implications are identified by Schuh et al. (2014), who discuss how cyber-physical systems and the Internet of Things will enable a new level of collaboration within the value chain. The article highlights four main ways in which I4.0 can increase productivity, namely: reduced product development cycles, improved decision-making capability through virtual engineering, shorter value chains and better performance than can be engineered through self-learning. Nevertheless, the focus is only on showing the potential business and operational benefits of I4.0 such as increased productivity and lower costs (Schuh et al. 2014; Pacchini et al. 2019); the wider organisational impact and any potential challenges are dismissed.

Against this backdrop, the available literature advances the view that I4.0 will not only result in a production or technical change, but also in extensive organisational consequences and opportunities (Bauernhansl, Schatz and Jager 2014; Botthof and Hartmann 2015; Schmidt et al. 2019). Furthermore, experts advise that established manufacturers should be conscious of the need to continuously innovate their business models in order to stay competitive in the new industrial landscape (Jonda 2007; Kagermann, Wahlster and Helbig 2013; Loebbecke and Picot 2015).

The literature points out that I4.0 is very popular from a technological perspective. Nevertheless, it is argued by authors such as Brettel et al. (2014) and Emmrich et al. (2015) that there is a backlog of research regarding the impact of I4.0 on wider business and BMs. The literature also shows that there is a gap in the analysis of which BM elements are likely to be affected by I4.0 and to what extent (Arnold, Kiel and Voigt 2016; Tirabeni et al. 2019).

Ehret and Wirtz (2017) have explored a different route to examining the impact of I4.0 on BMs by evaluating the economic impact of I4.0. The authors also argue that I4.0 will present new opportunities and threats that will not be addressed effectively with the current BMs. In the analysis of the economic impacts of I4.0, attention is focused on the arguable assumption that the information generated though the various I4.0 technologies will add value to the manufacturing/industrial process.

Ehret and Wirtz (2017) argue that such assumptions must be challenged, as according to economic theory, information only adds value under certain conditions. In a perfect market in equilibrium, information per se is unlikely to add value as market prices would match the customer requirements and demands with the full available capacity of economic resources. On the other hand, the study also argues that several economic research areas point out that uncertainty improves business prospects when customer needs remain unaddressed and economic resources are not fully utilised.

Other authors such as Amit and Zott (2001) and Wirtz (2016) are also aligned with regards to this level of uncertainty, linking it to entrepreneurship theory (focusing on the opportunities emanating from it) and transaction cost economics (focusing on the risks emanating from uncertainty). The literature points out that the new business opportunities will include: a- asset-driven ownership models, b- service and solutions innovations targeted at industry, and c- service and solutions targeted at end users. The literature also points out that I4.0 will enable better management of uncertainty downsides and encourage new BMs and non-ownership models.

This point is also argued by Kagermann, Wahlster and Helbig (2013), who proposed that I4.0 will lead to new ways of creating value via new BMs, enabling start-ups and small businesses to enter new markets and provide downstream services in their value network. Nevertheless, the above authors recognise the abstract level changes to the industry and to individual businesses and also point out that the changes in the value network will require a highly dynamic network of businesses rather than a single highly advanced business (Kagermann Wahlster and Helbig 2013; Thun et al. 2019).

Schumacher, Erol and Sihn (2016) offer a different perspective and argue that although academics and practitioners have envisaged significant economic gains via the digitalisation and integration of manufacturing businesses, such integration needs to reach across the entire value chain horizontally as well as across all layers of individual businesses vertically.

Furthermore, expert interviews performed by Schumacher, Erol and Sihn (2016) with practitioners and researchers have confirmed some of the research assumptions regarding common issues faced by companies seeking to implement Industry 4.0. These are listed below.

- Companies lack clarity on I4.0 definition
- This lack of clarity leads to uncertainty regarding risks and benefits emanating from the I4.0 implementation
- There is a lack of strategic guidance on how to approach the subject of I4.0
- This lack of knowledge impacts the ability to take coordinated measures to improve the status of their I4.0 implementation.

Thus, it is argued that the limited literature regarding the implications of I4.0 implementation for current BMs reflects the state of disagreement on both areas: first, the lack of clear definition and clarity around I4.0, and second, the lack of clarity on BM definition and adoption (issues to be addressed latter in this literature review; see section 2.3).

2.3.5 Business Models and Industry 4.0

The literature presents a consistent view that Industry 4.0 will impact upon existing business models. A survey from BDI (The Federation of German Industries, or Bundesverband der Deutschen Industrie e.V. – BDI 2014) has shown that over 84% of companies believe that digitalisation will have a significant impact on their business models, and major changes will be required. Against this backdrop, the available literature advances the view that the phenomenon of Industry 4.0 will not only result in a production or technical change, but also in extensive organisational consequences and opportunities (Bauernhansl, Schatz and Jager 2014; Botthof 2015; Schmidt et al. 2019).

Experts advise that established manufacturers should be conscious of the need to constantly innovate their business models in order to stay competitive in the new industrial landscape (Jonda 2007; Kagermann, Wahlster and Helbig 2013; Loebbecke & Picot 2015). It is also argued (Brettel et al. 2014; Emmrich et al. 2015) that there is a backlog of research regarding the impact of I4.0 on current manufacturing business models. It has also been argued (Arnold, Kiel and Voigt 2016) that the current literature on Industry 4.0 lacks an analysis of which BM elements are likely to be affected by Industry 4.0 and to what extent.

Kagermann, Wahlster and Helbig (2013) also discusses further implications for BMs on an abstract level (Kagermann, Wahlster and Helbig 2013: 22), stating that these new business and partnership models will focus on meeting individual customer requirements and enable SMEs to use services and software systems that they are unable to afford under current licensing and business models.

Similar points are also made by Dijkman et al. (2015), who argue that the current business models will not be suitable to capture new value to be generated by the adoption on I4.0. Furthermore, Dijkman and the The Economist Intelligence Unit (2013) both point out that the key question remaining is what business models will be applicable in this new environment. The latter point was also made by The Economist Intelligence Unit (2013).

Dijkman et al. (2015) provides a literature review on business models in relation to IOT and concludes that there is very limited knowledge of how BMs will be impacted and how the new BMs will differ from the old. In addition, Dijkman also combines the literature review of the available IOT BMs (Sun et al. 2012; Bucherer, Eisert and Gassmann 2011; Liu and Wang 2010; Li et al. 2013) with primary data in order to generate a BM framework for IOT applications. Nevertheless, this new BM framework adopts the Business Model Canvas (BMC) framework as the basis for a BM and justifies the choice due to the fact that Sun et al. (2012) and Bucherer et al. (2012) also utilised the BMC.

Although Dijkman has generated new sub-elements for the BMC (Osterwalder, Pigneur and Tucci 2005), it is argued that the reliance on the BMC elements as a guide to what a BM should encompass is questionable given the level of debate discussed above on BM definition and mix of elements. Therefore, it is argued that the conclusions from Djikman’s study are likely to be subjective, relying upon each respondent’s understanding of the BM and the choice of the BMC.

Gierej (2017) also provides a comparison between the BMC (Osterwalder, Pigneur and Tucci 2005) and the Lean Canvas (Leanstack 2016) in order to generate a new concept for business models to aid businesses implementing Industry 4.0. Furthermore, Gierej also selects the BMC as a representation of BMs, and makes a number of assumptions in order to offer a "new" IIOT framework which only modifies the value proposition component and adds further digital factors for consideration.

Finally, it is argued that the literature regarding BMs in the context of Industry 4.0 is generally limited to the description of new BMs in the sense of high-level business types (software as a service business model, servitization business model, etc.) (Brettel et al. 2014; Emmrich et al. 2015; Dijkman et al. 2015; Arnold, Kiel and Voigt 2016; Schuh et al. 2019). The literature is also typically presented in light of the uses of Osterwalder and Pigneur's (2002) BMC for surveys which explore the perceived impact of I4.0 on each of the selected BM elements for a particular business without the context of the integrated value chains.

This point is of particular relevance in the case of I4.0 horizontal integration of value chains which should be explored in the context of the relationships between businesses in such environment as a whole over an appropriate time frame, rather than internally focused on individual businesses.

2.3.6 I4.0 Literature Key Findings

Industry 4.0 is a relatively new topic in the literature, representing a new industrial paradigm, enabled by the development of the Internet, IT integration and the emergence of new technologies. Based on the above literature review, it is argued that key issues are still to be addressed.

There are important gaps in the I4.0 literature that need to be explored in order to enable both businesses and academia to progress with confidence in the face of risks and opportunities and support the UK manufacturers to achieve the expected benefits of the fourth industrial revolution.

The following list contains the most relevant gaps in the Industry 4.0 literature in the context of this research and its questions as set out in Chapter 1.

I - There is no clear and commonly accepted definition of Industry 4.0 in the literature. The different definitions found in the literature are positioned at distinct levels of abstraction, provided for different purposes and in different fields such as engineering, information technology and management.

II - The literature on I4.0 demonstrates that integration of the manufacturing industry is a critical factor in achieving the fourth industrial revolution. This will merge the operational technology (OT) with information technology (IT), into the I4.0 smart factory (Gilchrist 2016).

III - The literature demonstrates that I4.0 is much more than just deploying technology to improve the efficiency of individual businesses. Instead, it leads to a new level of value chain integration (horizontal integration), as well as smart business/factories, fully digitalised and integrated vertically.

IV - The literature recognises that I4.0 will lead to extensive organizational consequences for manufacturing and that manufacturers will be required to adapt in order to stay competitive. However, it is argued by the researcher that there is a gap in the literature regarding empirical, in-depth research evaluating the impact of I4.0 on manufacturers and their business models.

V - The literature lacks a comprehensive account of I4.0 in respect of the horizontal integration with some authors pointing out that there is a management research backlog on I4.0 (Brettel et al. 2014, Emmrich et al. 2015; Arnold, Kiel and Voigt 2016).

More importantly, it is argued that the literature review demonstrated that a gap exists in the I4.0 and the BM literature regarding the impact of I4.0 on manufacturing businesses, particularly in the case of horizontal integration of value chains.

It is argued that the literature regarding BMs in the context of I4.0 is generally limited to the description on new and abstract BMs in the sense of high-level business types (software as a service business model, servitization business model, etc.) (Brettel et al. 2014; Emmrich et al. 2015; Dijkman et al. 2015; Arnold, Kiel and Voigt 2016; Schuh et al. 2019).

In addition, it is also argued that, based on an analysis of the current elements of the various BM theories, and the fact that these elements invariably focus on a single business perspective and utilise the most suitable elements to describe that business, there is no single set of elements capable of covering all of the aspects necessary to evaluate the impact of the new highly collaborative and interconnected value chains emanating from the adoption of I4.0.

Finally, it can also be argued that there is a gap in regard to a study providing empirical evidence demonstrating the impact of Industry 4.0 on manufacturers' business models adopting this new paradigm. Such a study could provide the basis for a business strategy, business model and IP strategy framework to be deployed in order to support academia and practice to account for the impact of Industry 4.0 on current manufacturing business models in the face of the horizontal integration of businesses within the value chain.

2.4. I4.0 and Intellectual Property in Manufacturing

2.4.1 Introduction

The fact that innovation and collaborations are critical to an organisation's success, as well as to sustaining its competitiveness, is not a novel feature of business studies (Porter 1990; Teece 1986). On the contrary, a large body of research in innovation has already demonstrated the role and importance of innovation activities for a company's competitive position (Tidd and Bessant 2018). Nevertheless, other than literature from the legal, economic and business perspectives, academic studies on effectiveness of IPS for manufacturing businesses are limited (Reitzig and Puranam 2009; Hanel 2006).

It is also recognised in the literature that IP is a key asset, contributing to the value of businesses (Russell 2007). In the context of innovation and collaborations, companies often consider their IP rights as complementary assets (Teece, 1986; Reitzig, 2004) in order to assess the potential risks and opportunities regarding the acquisition of new intangible assets (Samson 2005).

With the acknowledgment of the need to be open and collaborative in order to innovate, businesses are encouraged to adopt IPSs to manage the process of internal and external development of innovation via the various methods available (Mehlman et al. 2010; Alexy, Criscuolo and Salter 2009). As such, IP management is arguably amongst the most challenging issues for a companies' senior management, along with the challenges of how to integrate innovation strategies and IP strategies (Samson 2005; Reitzig 2007) to address the increasingly complex value chains, such as the I4.0 horizontally integrated manufacturing value chains.

As discussed in the introduction, I4.0 is changing the automotive manufacturing industrial paradigm, and this will require manufacturing companies to adapt and develop new relationships and innovative capabilities. This research examines the implications of I4.0 on manufacturing BMs and IPSs. The study also seeks to support the formulation of more effective IPSs for the creation of competitive business strategies in existing and emerging manufacturing BMs.

The focus of this section lies on assessing the current literature on IPS, particularly with regards to risks and opportunities of strategic relevance for manufacturing businesses in inter-organisational relationships across their product or service life cycle, e.g. R&D, innovation processes, service provision, as well as in corporate strategy and decision-making.

In order to offer a broad picture, this literature review will cover the most relevant areas in the wider context of I4.0, namely: IP in general, IP from a legal theory perspective, IP from an economics perspective, IP from a business strategy perspective, and IP from an open innovation/knowledge exchange perspective.

This literature review is organised into the following sections: I) Introduction; II) Concept Theories; III) Appropriability; IV) I4.0 and IPS; and finally, V) IPS Literature Key Findings.

The following figure demonstrates the structure of the Intellectual Property Strategy section of this literature review.

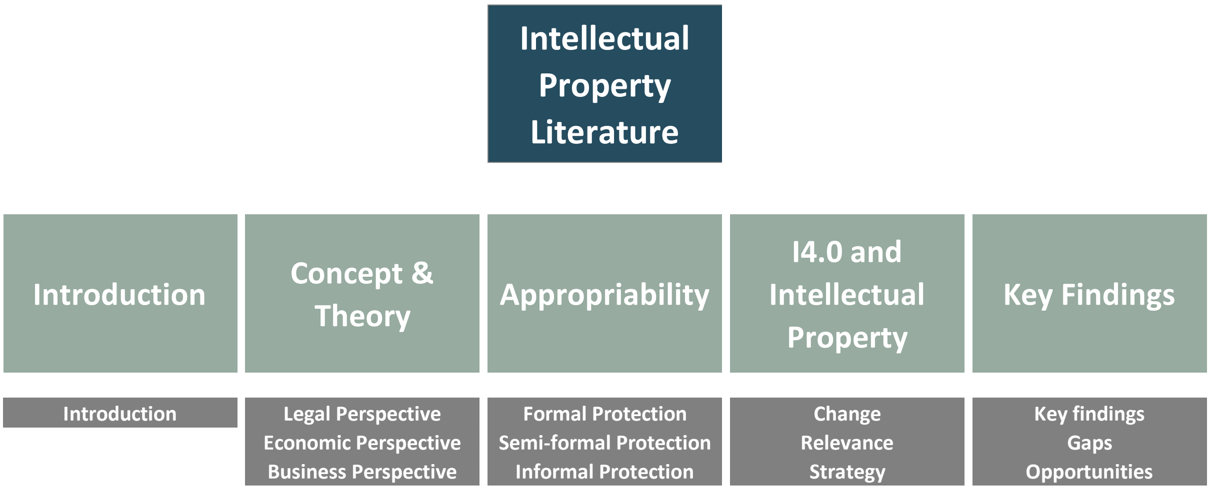

FIGURE 7 - IP LITERATURE REVIEW STRUCTURE

2.4.2 IP Concept and Theory

The topic of IP has been studied from a range of angles and perspectives. Nevertheless, three main points of view can be found in the available IP literature, namely: i) The legal scholar perspective; ii) The economics scholar perspective; and iii) The business scholar perspective.

The following paragraphs will explore each of these perspectives and their relevant literature.

IP – The legal scholar perspective

From a legal perspective, the term "intellectual property" can be interpreted as a combination of a number of legal concepts which govern the ownership of different types of intangible property (Fisher 2001). These legal concepts include: i) Copyright law, which protects original forms of expression including books, movies, music, and computer programs; ii) Patent law, which protects new inventions that comply with the patent registration criterion; iii) Trademark law, which protects things such as words and symbols used to identify the goods and/or services provided by a particular business; iv) Trade-secret law, which governs the protection of a business's valuable commercial information from its competitors.

The four main "theories" or analytical constructs found in the literature can be categorised as: (i) Utilitarian theory (maximising net social value); (ii) Lockean theory (rights to the product of his/her effort); (iii) The protection of personality in works; and (iv) Social planning theory (a fair and just society) (Fisher 2001).

The following paragraphs will briefly explore each of these theories, starting with the utilitarian theory.

The utilitarian theory is based on economic principles and focuses on explaining how IP can potentially deliver the Benthamite vision (Bentham 1839) of "the greatest good for the greatest number" (Landes and Posner 1989: 325). This theory emphasises wealth maximisation and aims at balancing the social costs and benefits related to the societal effects of IP laws and rules (Mill 1862;

Landes and Posner 1989). Whilst this theory has generated a number of interesting propositions on how to achieve this vision of balance, it has been argued that it cannot provide a robust way to measure inputs, outputs and the related process (Fisher 2001).

Next, the Lockean theory is based on John Locke's vision of property rights (Hughes 1998). For Locke a person should be able to enjoy the "fruits" of his labour, which converts a raw material into a product, thus adding value (Locke 1970). This theory holds that it is the state that has a duty to protect and enforce natural rights derived from one's labour.

The main issue with this vision is that it fails to explain why labour added to a resource should give rise to entitlement to a property right in such a resource. Furthermore, it also fails to clarify how far one's rights should go, as pointed out by Robert Nozick: "If I pour my can of tomato juice into the ocean, do I own the ocean?" (Nozick 1974: 178-182). As a result, it is argued that the application of the Lockean theory leads to an unmanageable level of uncertainty.

Next, we consider the personality theory, which promotes property rights only and whether they contribute to the promotion of 'human flourishing' by offering protection and/or fostering the fundamental human needs. This theory's uncertainty, according to Wilkof (2014), is evident as the needs or interests to be promoted are subjective. Fisher (2001) attempted to identify four needs deemed appropriate for IP protection, namely: privacy, individual self-realisation; identity; and benevolence.

However, it is argued by Wilkof (2014) that there is no agreement on the application of such conflicting needs as, for example, it would be expected of a reasonable people to disagree on whether the protection of trade secrets is a need with regards to privacy, as the right of privacy of a particular person provides the right to disclose his private information to a confined number of friends in the assumption that such information will not be disclosed to the entire world (Hughes 1998: 330-350).

The final theory, known as social planning theory, was proposed and explored by a number of well-known academics and philosophers (Jefferson 1972, Marx 1844, Fisher et al. 1993; Michelman 1998). This theory differs from the utilitarian theory in that it seeks to go beyond the notion of "social welfare" to a much broader vision of society supported by IP (Combe 1991). It is argued that the main flaw with this theory emerges from the fact that it does not, and cannot, achieve a consensus as to the goals that such "social planning" seeks to achieve (Wilkof 2014).

In conclusion, there is a great deal of debate about the theories and concepts justifying IP law from a legal point of view. Nevertheless, as Fisher (2001) points out, even if none of the above theories can provide fully satisfactory justification for IP law, at least they can focus the minds of people and institutions responsible for improving the law and addressing their inadequacies.

Having discussed the high-level IP theories from a legal scholar's point of view, which is arguably very interesting but does not support the researcher in answering the research questions, attention will now turn to the economics scholar's perspective.

IP – The economics scholar's perspective

A review of the IP literature emanating from economics scholars shows IP in a distinct light, as a variable of economic growth, within a given economy. From the economist's perspective, a good IP model should contribute to the growth of an economy. These scholars debate the way in which IP law could and should be transformed to improve economic growth. Such debates are typically based on two main justifications. Firstly, it is argued that IP law should foster development and innovation (Boldrin and Levine 2002), and secondly, it is also argued that innovations result in direct economic growth (Besen and Farrell 1991).

The key premise of the economic theory rests on the view that a good IP system should foster innovations, which in turn lead to a higher rate of economic growth (Gould and Gruben 1996, Eiche and García-Peñalosa 2008; Dinopoulos and Segerstrom 2010).

Typically, economics scholars rely on mathematical models to explain the potential effects of a given IP policy on the economy. They also rely on such models to make assumptions as to the cost of a given innovation, its value and/or for how long it should be protected. By doing so, economists have reached conclusions regarding various aspects of IP, for example: i) IPR enhances the economy where R&D is high, but not when R&D is at low levels (Shavell and Ypersele 2001); ii) the economic benefits of copyright outweigh the detriments (Boldrin and Levine 2002) and finally, iii) under-protection of IP causes greater losses to the economy than those losses caused by the application of strict IP laws (Kwan and Lai 2003).

The literature from the economics scholar's perspective relies on data from various sources and in various forms in order to reach their conclusions. Höffner (2010) relied on historical data to compare the economies of Germany and the British Empire during the eighteenth and nineteenth centuries, in order to conclude that the absence of copyright law in Germany contributed to better performance in comparison with the British Empire. In the same vein, Coriat and Orsi (2002) have also used historical data to explain IP law changes and their impact on the economy. Others have demonstrated a correlation between patents and GDP (Gould and Gruben 1996).

The literature also demonstrates the use of logical arguments to derive conclusions about IP law from a particular stance. This is the case with one of most popular papers in this area, Heller's (1998) 'The Tragedy of the Anti-commons'. In this seminal work, Heller explains how patents in the medical area can prevent the creation of useful and cost-effective products resulting in economic failure (Heller and Eisenberg 1998). Hall (2007) also relies on a logical argument to contend that the homogeneous protection of inventions in distinct industries is counterproductive, as a patent, for example, can be an incentive to one business, and at the same time a necessary evil for another.

It is argued that, overall, the IP literature from the economics perspective is extensive, but also often conflicting and contradictory. For example, Jaffe (2000) points out that after an extensive literature review of IP from an economics perspective, it was very difficult to reach any significant conclusions. One could argue that the review of the literature on IP from an economics stance demonstrates that there is a tendency to conclude that weaker IP laws could lead to more innovation and economic growth. However, as pointed out by Coriat and Orsi (2002), the tendency even back in 2002 was to make changes to introduce stronger IPRs (Coriat and Orsi 2002). This suggests that legislators have shown a tendency to contradict or ignore economists with their actions.

In this particular point, the literature on IP from an economic perspective could be interpreted in the context of I4.0 horizontal integration as leading to a weaker IP model where data, information, knowledge and other intangible assets are shared though the integrated value chain, thus resulting in more innovation and economic growth. Nevertheless, even if this interpretation is correct and in general more economic growth is generated, there is no way to ascertain how this economic growth will be distributed, which businesses are likely to capture more or less value and what is the most effective IP strategy in each case.

In order to attempt to answer some of these questions, having explored the IP literature from an economics stance, attention will now turn to the business scholar's perspective.

IP – The business scholar's perspective

The IP literature from a business perspective typically offers a narrower scope, focusing not on the whole IP system but rather on individual actors within a given system, in essence companies. The business scholar may consider the rules of the system as a given, and describe how businesses can or should behave within these boundaries. The main drive of the business scholar's stance is to look at IP as critical to the establishment of a company's strategy regarding innovation and the protection of innovation (Taylor and Silberstone 1973; Teece 1986; Gassmann and Enkel 2011).

The IP literature from a business perspective often considers the management of technology and innovation within a business or a business relationship. The articles typically span the entire process from an initial idea, all the way to realised innovation which is offered to the market. Furthermore, the tendency in the literature is to split the technology and innovation process down into two sub-processes. These are labelled creating value and capturing value (Leiponen 2008; Reitzig and Puranam 2009).

The first sub-process, creating value, focuses on the generation of innovation (Teece, Pisano and Shuen 1997; Amit and Zott 2001; Thomke and von Hippel 2002). The second, capturing value, focuses on how companies can best exploit their technologies and innovations (Teece 1998; Chesbrough and Rosenbloom 2002). Furthermore, IP is sometimes also considered in the entrepreneurship context (Lichtenthaler 2008) and even strategic management (Somaya 2003; Leiponen 2008; Reitzig and Purunam 2009).

Given the scope of this research and its objectives, having explored the IP literature from the legal and economics perspectives, it is clear to the researcher that the business scholar's perspective is the most relevant in the context of this study, which looks at examining how I4.0 is affecting value creation and capture in manufacturing businesses and what can be learned from this examination in order to address risks and opportunities in this new paradigm.

One IP theory in particular is focused on how value is generated and captured by businesses in a given set of relationships, the theory of appropriability. The term represents the degree to which a business can capture revenues from its innovation, and how quickly or easily the competition can replicate a given innovation.

Appropriability provides a theory that offers a method to assess some of the risks associated with changes in relationships in the context of value generation and capture. In doing so, the theory supports the objectives and questions of this study which seek to explain how I4.0 affects the manufacturing value chain by changing its relationships through horizontal integration of businesses, which in turn affects the existing innovation and competition paradigms for this particular industry.

2.4.3 Appropriability and IP in Manufacturing

As argued by Teece (1986), appropriability is a critical factor to the effectiveness of innovation. If a company innovates very well but fails to appropriate such innovation, its competitors will imitate and commercialise the innovation without the costs of research and development incurred by the original innovator. Without appropriation, the initial company has no incentive to invest in innovation. From this point of view, the legal, business and economics theories are directly linked because, at an individual firm level, a company must be able to appropriate its innovations in order to generate value, which is then re-invested in order to continue innovating. On the other hand, on a system-wide level, the law must provide the conditions necessary to ensure that companies are able to appropriate their innovations in order to contribute to the growth of the economy.

As pointed out in the previous section, several economists disagree with this argument, countering that a legal system with weak IP protection contributes to higher economic growth. However, it is an undeniable fact that companies need to carry on innovating to stay competitive in the market (Arrow 1962). If companies slow down or stop their innovation cycle, their competitors are likely to become more efficient and reduce their costs and in turn take a larger section of the market.

Independently of how good or bad a given IP system is, and whether such a system promotes or hinders innovation, all companies within a jurisdiction will be subject to this system and have to devise strategies to operate within this environment in the most effective manner in order to protect their innovations. Business scholars attempt to understand and describe how businesses behave and their theoretical motivations to act in the manner in which they do.

Over three decades have passed since Teece's (1986) article 'Profiting from Technological Innovation: Implications for Integration, Collaboration, Licensing and Public Policy'. Nevertheless, appropriation is still a popular topic in the IP literature emanating from business scholars. Recently, a number of fundamental questions regarding this area of research were explored and answered

(Teece 2010). Of particular relevance is the fact that the concept of generating value from innovation has been transformed over the last few decades from a concept based completely on financial returns or value from innovation, to a model which expanded into other forms of intangible value such as competitive advantage, brand recognition, time to market, etc. Teece's article (1986) is arguably viewed as empirically based reasoning that introduces the concepts of transaction costs and evolutionary economics into a framework supporting the examination of how companies approach the innovation process (Jacobides and Billinger 2006).

The literature shows that appropriability is changing and dynamic aspects are emerging. This fact does not affect the concept of appropriation but rather indicates that in today's globalised markets, the complexity of the innovation process and IP appropriation has increased. Such a rise in complexity can be associated with the fact that the company's ability to appropriate an innovation and the financial success of such innovations are no longer linked, as not every innovation is designed to result in direct financial returns.

Innovative products and solutions are designed as a way to enter and remain relevant in certain markets, and return on investment is typically generated only at a later point (Teece 2010). In this new era, there are even cases in which an innovation is successful only due to its imitation by the competition (Chesbrough 2007). For example, this is the case with technologies such as open source software, where the innovation is only successful due to the fact that, within the limits of the open source licence, anyone is free to copy, collaborate and improve the software (von Hippel and Von Krogh 2006). It is argued that new and complex structures are now evident in the literature, thus demonstrating the ongoing importance of IP appropriability as a topic of interest for business literature and practice (Nonaka, von Krogh and Voelpel 2006).

The literature in this area has experienced a paradoxical period in the 20 years preceding the turn of the millennium. A number of studies from Mansfield (1984), Levin et al. (1987) and Cohen, Nelson and Walsh (2000) argued that companies increased their number of patents at the same time as they reduced their reliance on patents as a method of appropriation. Such a phenomenon, termed the ‘patent paradox’, was analysed by Hall and Ham-Ziedonis (2001) who investigated why the number of patents per company was increasing if the companies were less reliant on patents. The study was based on interviews with companies in the semiconductor industry where they answered a number of questions related to the justifications for increased patenting activities.

The results of the interviews showed that the main reason for increased patent use was that the companies were using the patents as valuable assets for negotiating deals. Such a tactic was justified by the fact that the ever-evolving semiconductor industry was prone to patent infringements, and these infringements would regularly be dealt with outside the courts by various licensing arrangements between the businesses (Grindley and Teece 1997).

These licensing arrangements would typically take place in the form of cross-licensing agreements which enabled company A to use company B’s patents in exchange for a licence for Company B to do the same with company A’s patents. These licensing arrangements work well, as both companies have clarity regarding the ownership of the IP. This solution can also provide a defence mechanism, as the parties are aware of the potential to take infringement cases to the courts and the costs and time associated with this course of action.

It can be argued that the efficacy of these licensing arrangements explains the ‘patent paradox’, as although companies were relying less on patents for appropriation, registering a patent was a key factor in achieving the licensing agreements and the main motivation for the increase in the patent use by businesses (Hall and Ham-Ziedonis 2001).

Hall and Ham-Ziedonis’s (2001) research also used patents and other formal types of IP as a protection mechanism to minimise the risks of litigation from potential cases initiated by their competitors. In addition to formal IP, an article by Cohen, Nelson and Walsh (2000) also demonstrated that companies tend to focus on utilising a range of informal measures to support the appropriation of innovation. Cohen and Walsh (2001) collected data from 1,478 research and development departments of firms based in the United States and found that the most common informal methods utilised for appropriation were keeping innovations secret and utilising lead time advantages (e.g. being the first in the market with that particular innovation and establishing a brand or standards in relation to that particular innovation).

It can also be argued that this is an example of how companies have changed their IP strategies in order to effectively protect and appropriate value in a dynamic context where there is a change in paradigm. This is also the case for manufacturers in the automotive value chain, and appropriability as a theory could be used to support understanding of this change and identifying actions to address risks and opportunities.

The literature also demonstrated that the phenomenon of Open Innovation (OI) had a great influence on practices related to appropriation. Chesbrough (2003) describes OI as a tendency to increase the level of collaborations in R&D. Such an increase in collaboration can result in changes to the appropriation paradigm, where closer partnerships required companies to share an increasing amount of IP. Furthermore, it was also argued by Chesbrough (2003) that OI transformed IP into a commodity which was adopted by more and more companies that traded their licences rather than just developing and commercialising products in their markets (Chesbrough 2006).

The appropriation literature is arguably constructed upon two main principles. The first is the assumption that, if necessary, the owner of a formally protected IP could resort to the courts for the enforcement of his/her rights. The second principle is the assumption that, if necessary, the IP owners would have the required financial means and resources to litigate and enforce their rights.

With regard to the first principle, the ability to resort to the courts for the enforcement of the IP rights is exactly what gives rise to the value in IP, as the fear of enforcement is the only factor that keeps other businesses from infringing or appropriating the IP owned by a business. As previously discussed, it is common for patents to be utilised for reasons other than mere protection of innovation (Hall and Ham-Ziedonis 2001). Nevertheless, it is argued by Shapiro (2003) and Jaffe and Lerner (2004) that regardless of the reasons for which patents are utilised, firms have always relied on the assumption that these patents, if necessary, would be enforced by the courts.

In respect of the second principle, the appropriation literature is based on the assumption that the companies and individuals owning IP would have the necessary resources to enforce their rights. This assumption is appropriate in most of the studies, as they investigated the practices found in large companies which typically committed large budgets and provisos to ensure that the right levels of appropriation were guaranteed by their IP departments, patent attorneys and specialist engineers (Blind and Thumm 2005). However, this assumption is not true of small and medium companies, which make up a large proportion of the automotive manufacturing industry.

Hurmelinna-Laukkanen and Puumalainen (2007) conducted a review of the appropriability regime literature and explored how a given regime is made of different protection mechanisms that can be used by businesses in order to protect innovations and have the best change to secure a return on investment in innovation. In this work the authors explored the key building blocks of appropriability and listed the following as the key protection mechanisms that can be used to define an appropriability regime:

I- The nature of knowledge

The nature of knowledge was presented by the authors as one of the most important indicators for appropriability. Knowledge in this context can be categorised as explicit (perhaps digitalised is the appropriated term in the context of I4.0) or tacit and unintelligible in various silos across the business. In scenarios where the knowledge related to a particular innovation is explicit knowledge the potential for replicability is high as the knowledge in relation to the innovation is easy to copy. Businesses innovating in areas with explicit knowledge should evaluate the importance of this information for the business' value proposition in order to derive an effective protection strategy (Hurmelinna-Laukkanen and Puumalainen 2007).

On the other hand, tacit knowledge provides a barrier to replicability as it is harder to copy due to the fact that this knowledge is typically embedded as part of the business routines and capabilities (Teece 1995). This is the most common type of knowledge in manufacturing businesses as it is normally difficult to document because it is spread across the entire company in multiple department and employees heads. According to Polanyi (2012) the contrast between explicit and tacit knowledge is evident for example in the case where a competitor can gain explicit knowledge through reverse engineering, but fails to obtain the tacit knowledge required to replicate a particular innovation as the latter can only be gained through practical experience.

II- Institutional protection

The second protection mechanism explore by the authors is entitled institutional protection and focuses particularly on the use of intellectual property rights as a protection mechanism. These rights include patents, copyrights, trademarks, trade and secrets. Furthermore, other methods of protection such as contracts and other practical means of protection such as secrecy in process or product development are also part of the protection mechanisms under the umbrella of institutional protection which can prevent key knowledge to be acquired by competitors (Hurmelinna-Laukkanen and Puumalainen 2007).

III - Human Resource Management

Human resources, particularly employee retention has been emphasised as key for appropriability, particular in tacit knowledge intensive businesses as the employees are form a critical part of the intangible assets required for creating value. Building effective employment contracts and developing a strong culture of employee engagement should also be part of an appropriability strategy (Hurmelinna-Laukkanen and Puumalainen 2007).

IV – Practical Means

Hurmelinna-Laukkanen and Puumalainen (2007) also proposed that practical means of protection is an important building block of the appropriability regime. In this perspective, practical means refers to the practical steps taken by a business to protect the data and information related to its innovations. Examples of the use of practical mean can be found in passwords policies, employee training on IP and data security and many other activities designed to prevent undesired sharing and copying of important data which can impact the potential appropriability of an innovation.

It can be argued that there is a strong overlap between practical means of protection such as secrecy, trade secrets and contractual agreements which are part of other building blocks such as IPRand Human resources management, and a potential consolidation of the building block with an number of apppropriability indicators would facilitate the actual evaluation of appropriability regimes.

V - Lead time

The last building block of appropriability regime as proposed by the authors is lead time, which arguably is not a protective mechanism, but rather a strategic and tactical approach to derive competitive advantage by being the first to market with an innovation and maintaining and improving the innovation continuously to keep ahead of the competition which will constantly catch-up with the innovator.

The definition of the building blocks of an appropriability regime provide an important contribution towards the evaluation of the impact of change on a particular scenario such as the implementation of I4.0 horizontal integration. However, the literature falls short of providing any example of application of this construct to a scenario such as the transformation in the manufacturing supply chain. Furthermore, there is also a gap in regards to a framework or tool which can be applied by businesses seeking to assess the risks and derive new IP strategies.

Drawing a conclusion, the researcher argues that most literature on appropriation is based on large companies that are already heavily involved in innovation and have robust appropriation mechanisms in place (Levin et al. 1987; Grandstrand 1999; Cohen Nelson and Walsh 2000; Cohen et al. 2002). These studies led to a better understanding of the practices emanating from these large businesses. Nevertheless, the literature sheds little light on situations where the two principles above are not true.

From this perspective, it can be argued that there is a gap in the understanding of the behaviours and practices of small, medium and large companies that are just beginning to engage in collaborative practices. This is the case for a large proportion of manufacturing companies implementing the interconnected and highly collaborative I4.0 value chains.

Having discussed the literature on IP appropriation, attention will now turn to the literature on IP in the context of Industry 4.0 and manufacturing businesses.

2.4.4 Industry 4.0 and IPS

The available literature demonstrates the paramount role of intellectual property (IP) in the functioning of collaborative and knowledge exchange initiatives (Teece 1986; Chesbrough 2006; Hertzfeld, Link and Vonortas 2006; Pisano 2006; Teece and Pisano 2007; Slowinsky et al. 2009; Lichtenthaler 2010). It is argued that the relationship between the different types of IP in inter-organisational relationships is still a topic for debate and should be subject to studies in the future (van de Vrande, Vanhaverbeke and Gassmann 2010).

The literature also recognises a distinction between using IPS in regard to the collaborative projects in the context of ‘fuzzy’ or undefined objects (e.g. where the innovation boundaries and outcomes are unclear) and using IPS in those collaborative projects where the object of the collaboration is well defined (e.g. well-understood innovation projects with clear objectives) (Bader 2008). However, the current literature is not clear with regards to the role of IPS in the context of these new inter-organisational relationships emanating from the implementation of I4.0, and how IPS can, or should, be used at the different stages of transformation in order to maximise the opportunities and to mitigate the risks.

The available literature points to a number of IPPMs that are available to support knowledge exchange and collaborations in inter-organisational relations. These will range from 'hard' IP rights, such as patents, design rights, trademarks, trade secrets and copyrights, to medium IP rights, such as contractual agreements, non-disclosure agreements (NDAs) and collaboration agreements, all the way to soft measures such as the use of complex products and/or processes, secrecy, human resources management and lead time advantages (Arundel 2001; de Faria and Sofka 2010; Laursen and Salter 2014).

There are very few publications regarding the impact of I4.0 on businesses' IPS, although the available literature widely recognises that I4.0 will affect organisations in this area. For instance, Kagermann, Wahlster and Helbig (2013) argue that, under the new industrial paradigm, horizontally connected businesses will be faced with existing organisational practices and legislation that will need to be adapted to suit the new organisations and technologies. He also argues that businesses will be faced with challenges, including the protection of corporate data, liability issues, handling of personal data and trade restrictions.

Despite the recognition of the changes in the industrial paradigm, it is argued that the literature is silent in regard to a practical analysis or guidance of how this change will impact businesses (Kagermann, Wahlster and Helbig 2013). What is arguably clear, on the other hand, is that these challenges should be dealt with by businesses themselves who will need to be vigilant to the risks and opportunities emanating from I4.0.

A report produced by the Federation of German Industries (Bundesverband der Deutschen Industrie) and the law company Noerr LLP (BDI Noerr – Industry 4.0 – Legal Challenges of Digitalisation 2015) presents a similar view, offering seven challenging areas in respect of Industry 4.0, namely: data protection, data ownership, IT security, IP law, standards and contracts, liability and autonomous systems. The report is based on data collected from 500 German companies where 91 legal departments were surveyed to validate and assess the legal challenges emerging with regards to the digitalisation of business.

Industry 4.0: IP Law Stance

It is argued (Beldiman 2015) that this new manufacturing paradigm enables better creation and dissemination of knowledge, whilst opening up the market to new players and new forms of relationships. This results in an environment where competitive advantage no longer necessarily rests on exclusive knowledge, but instead, on the ability to access knowledge from the right source at the right time.

There are very few studies exploring the impact of I4.0 on IP law. The available literature appears to point out that with the increase in digitalisation, connectivity and collaboration between businesses, the risks of losing potential IP in the form of trade secrets and critical know-how will exponentially increase (Kagermann, Wahlster and Helbig 2013; Millien and George 2017; BDI Noerr 2015; Prause 2015).

It is argued by Kagermann, Wahlster and Helbig (2013) that upcoming changes to the protection of undisclosed know-how will undoubtedly impact IP and IP strategies. However, the onus is on businesses who will bear the burden of proof in actions for illicit loss of trade secrets and will have to prove that adequate measures to protect the know-how in question were taken.

On the same point, BDI Noerr (2015) points out that this has wide-ranging implications for contractual agreements which should include effective confidentiality clauses, and clauses protecting against competition, including the case of a business's employees who may hold special knowledge. Attention is also brought to the requirement to review current contracts and ensure that outdated and/or ineffective clauses are addressed.

Industry 4.0: Contract Law Stance

Once again, the literature on the impact of I4.0 on contracts is very limited. However, it is pointed out that businesses will have to be watchful and diligent in understanding the impact and challenges emerging from digitalisation at individual contract level, especially with regards to the protection of data as a source of value and economic good, protection of know-how, the allocation of rights in collaborative projects and open innovation. It is also proposed that a standardised contractual structure should be sought, as well as model contract provisions suitable for small- and medium-sized companies (Kagermann, Wahlster and Helbig 2013; Millien and George 2017; BDI Noerr 2015; Prause 2015).

The available literature also argues that the contractual aspect will be very important for SMEs, who must ensure that the appropriate protection mechanisms are in place to secure trade secrets, whilst at the same time ensuring that the results of the new business models are shared out proportionally. It is argued that it is necessary to precisely define and agree the roles and contributions from each of the partners as tightly as possible (Kagermann, Wahlster and Helbig 2013; BDI Noerr 2015).

After reviewing the literature, it is evident that there is a gap regarding a detailed analysis of the impact and implications of Industry 4.0 for business contractual relationships, particularly with regard to differences and similarities of each business model (current or new) and the position of the particular manufacturing business within the value chain.

Based on a critical assessment of the literature, the researcher argues that in order to appreciate and discern the challenges posed by I4.0, research must be conducted to analyse the phenomenon via an interdisciplinary lens, which places technology, business management and legal aspects in context.

As pointed out by Kagermann, Wahlster and Helbig (2013) and Millien and George (2017), it is of paramount importance that the legal, engineering and management teams have a common language in order to appreciate and debate the emerging issues and opportunities surrounding the process of designing and implementing I4.0 in current and future businesses.

With the above limitations in mind, the following sections of this chapter will seek to offer a literature review assessing the potential relationship challenges to be faced by businesses in the new inter-organisational relationships in the networks emanating from I4.0. It will provide a comparison with a broader view of intellectual property strategy in the context of networks, collaborations and innovation.

Intellectual Property Protective Measures and Application (IPPM)

The available literature differentiates between the legal and contractual mechanisms for IPPM (such as patents, design rights, trademarks, copyrights, trade secrets, employment contracts, Non-Disclosure Agreements and confidentiality agreements) from strategic IPPM tactics such as design complexity and lead time advantage (Gallié and Legros 2012; Laursen and Salter 2014).

The literature also points out that the legal IPPMs provide protection only in the form of litigation, infringement and counterfeit. The effectiveness of IPPM is described as effectiveness in securing the appropriation of revenue emanating from the commercial exploitation of the intangible assets the protective measure is set out to protect (Teece 1986; Arundel 2001; Hertzfeld, Link and Vonortas 2006).

A number of papers provide an analysis of IPPMs with the aim of identifying the most suitable and effective tools to protect different relations, collaboration or innovations in a particular industry, business type or innovation type (Teece 1986; Levin et al. 1987a). The literature also provides evidence that IPPMs such as patents are very effective in industries such as pharmaceuticals. Such IPPMs have proven to be less effective in industries such as consumer electronics, due to the tendency of appropriation by 'inventing around' (e.g. making small variations to the invention in order to avoid infringement whilst utilising some of the protected IP) (Cohen et al. 2002; Hussinger 2006; Somaya, Teece and Wakeman 2011).

More importantly to the scope of this research, the available literature provides empirical studies showing that SMEs tend to rely less on IPPMs such as patents than large companies. This is due to fact that the costs associated with IP and the financial constraints faced by small and medium companies limit their strategies in relation to the adoption of informal protection measures like trade secrets (e.g. keeping the IP in secret) (Arundel and Kabla 1998; Baldwin and Hanel 2003).

In this vein, it can be argued that this particular finding, when applied to the I4.0 context, where small and medium business will form part of highly interconnected and collaborative value chains whilst having limited formal IPPMs at their disposal, will potentially place such businesses in a disadvantageous position with increased risk in terms of loss of intangible assets and capture of value.

The literature highlights the fact that quantitative studies are the most common type of research into IPPMs. Such studies are focused on understanding differences in IP management practices between companies of various sizes, in different sectors, industries and even countries (Candelin-Palmqvist, Sandberg and Mylly 2012). The use of qualitative research methods such as case studies and in-depth interviews is less prominent.

The majority of studies focus on the choice between patents and trade secrets, and very few papers explore how the different IPPMs could potentially be combined into a strategy to enhance one another and support businesses in protecting their IP in inter-organisational relations collaborations (Hussinger 2006; Landry, Amara and Saihi 2006; Hanel 2008; Gallié and Legros 2012).

Henkel, Baldwin and Shih (2013) argue that 'IP modularity', a construct that is aimed at accounting for business requirements to generate and capture value from IP, enables the business to choose which IP should be deployed/shared in each scenario.

This approach is intended to provide a solution that avoids conflicts and reconciles the risks and opportunities in the paradox of collaborative innovation where – in order to innovate – collaborators must have a level of openness whilst, at the same time, deploying mechanisms for the appropriation of value that typically require a level control and secrecy.

Authors such as Hussinger (2006) suggest that different IPPMs should be used at different stages in regard to collaborations on new product development processes. IPPMS should be aligned with the degree of uncertainty at each stage of the development project (Hussinger 2006; Trott 2008).

In this approach, trade secrets are deployed at early stages of the collaboration project, as the uncertainty levels regarding the project outcome are high (e.g. it is difficult to identify in detail the likely outcomes of an innovation project). However, IPPMs such as patents could then be deployed as the project reaches a certain level of maturity and the uncertainty surrounding the innovation is reduced. At this stage, there should be clarity on the project outcomes, as well as how the innovation is likely to be commercialised.

IPPMs in the context of inter-organisational collaborations

There is a large body of literature available in the context of Open Innovation (OI), with some authors arguing that this is one of the most important areas investigated in the last decade (van de Vrande, Vanhaverbeke and Gassmann 2010; West et al. 2014). A very interesting tension emerges in this field between protection requirements and sharing (Bogers 2011), in the form of a theory known as the "Paradox of Openness" (Laursen and Salter 2004, 2006).

Table 1 provides a list of the most common IPPMs available in the literature.

#	Stage	Key Characteristics
I	Patent	A patent is an exclusive right granted for an invention. Patents provide their owner with the right to decide how or whether the invention can be used by others. Such right and associated protection is available to the patent owner for a limited period, typically for 20 years.
II	Trademark	A trademark is a sign capable of distinguishing the goods or services of one enterprise from those of other enterprises. Trademarks can typically be renewed indefinitely.
III	Industrial design	An industrial design – or simply a design – is the ornamental or aesthetic aspect of an article produced by industry or handicraft; registration and renewals provide protection for, in most cases, up to 15 years
IV	Copyright and related rights	Copyright is a legal term used to describe the rights that creators have over their literary and artistic works. It includes books, music, paintings, sculpture and films, as well as computer programs, databases, advertisements, maps and technical drawings. Related rights are granted to performing artists, producers of sound recordings, and broadcasting organizations in their radio and television programmes.
V	Trade secrets/Confidential information	A trade secret/undisclosed information is protected information that is not generally known amongst, or readily accessible to, persons that normally deal with the kind of information in question, has commercial value because it is secret, and has been subject to reasonable steps to keep it secret by the person lawfully in control of the information
VI	Non-disclosure agreements (Employee, Confidentiality, Memorandum of Understanding)	Non-disclosure agreements are legally binding contracts establishing the conditions under which one party (the disclosing party) discloses information in confidence to another party (the receiving party).
VII	Product or process complexity	Product or process complexity can support appropriability of innovation, thanks to the difficulty of integrating different technologies, components, and systems.
VII	Lead time advantage	Lead time advantage is the ability to be first on the market and consequently ahead of rivals.

TABLE 1 - IPPMS SOURCE – MODIFIED FROM MANZINI AND LAZZAROTTI (2015)

The Paradox of Openness refers to a situation where a business faces the dilemma of considering the need to protect the companies' know-how, technology and core competencies which are required to enable value creation, whilst at the same time considering the need to be open and to collaborate with other organisations in order to innovate (Pisano 2006; Chesbrough, Vanhaverbeke and West 2006).

The available literature provides a comprehensive analysis of the Paradox of Openness. However, there is a gap in regard to the new value chains emanating from the adoption of I4.0, which will exacerbate the issues related to sharing intangible assets in the manufacturing value chains due to the quantity and complexity of relationships and the depth and volume of information shared between businesses.

The literature highlights the challenges and risks emanating from the open and collaborative projects with regards to value capture and the appropriation of innovation (Alexy, Criscuolo and Salter 2009; West and Bogers 2011; Henkel, Shoberl and Alexy 2014). Furthermore, researchers have also explored the risks regarding the loss of unique know-how and knowledge spill-overs between collaborators (de Faria and Sofka 2010), as well as the risks associated with opportunistic behaviours by collaborating partners (Vangen and Huxman 2003).

Granstrand and Holgersson (2014) provide a research study on opportunistic behaviours in relation to collaborative projects, at the point when the projects are concluded or when one of the leading participants leaves and highlights the challenges in relation to disentangling and allocating IP rights amongst the partners.

In the same article, Granstrand and Holgersson (2014) have also argued that IP managers should focus on the risks related to IP disassembly in general, as well as to Sideground IP (IP generated by a business at the same time as a collaboration, but outside the scope of the collaboration), and Postground IP (IP generated on the same subject but after the termination of the collaboration) knowledge specifically.

The literature also points out that contractual provisions must be applied to mitigate issues related to IP disassembly in collaborations. However, on their own, contracts are not sufficient and should be complemented by other non-contractual relationships and dependencies (Millien and George 2017).

Another strand of the literature explores the role of IPPMs as enablers or disablers for collaborations and open innovation, a valuable perspective of the new horizontally integrated manufacturing value chains and I4.0. It is argued in the literature that IPPMs are the 'currency of Open Innovation' and enable collaborative relations and innovation activities (Gallini 2002; West 2006; Alexy, Criscuolo and Salter 2009).

On the other hand, it is also proposed by Hertzfeld, Link and Vonortas 2006 and Bogers (2011) that IPPMs such as trade secrets are disablers of collaborative relations as they compromise the success of such relations by demonstrating a lack of trust amongst the partners. It is argued that closeness and secrecy could be incompatible with collaboration and Open Innovation, as typically collaborations imply openness and knowledge sharing. Nevertheless, IPPMs such as patents and well-drafted contracts and other forms of agreement are regarded as essential to the facilitation and enablement of such relationships (Hertzfeld, Link and Vonortas 2006; Bogers 2011).

In summary, it is argued that the literature recognises that IP strategy and management play a critical role in the success and effectiveness of collaborative relations, as well as supporting businesses in sustaining their competitiveness (Porter 1990; Teece 1986).

Other than literature from the legal, economic and business perspectives, academic studies on effective IP strategies for businesses are limited (Reitzig and Puranam 2009; Hanel 2006). It is also argued that a gap in the literature exists in regard to IP strategy and IP management in relation to collaborations in the context of I4.0 and the new inter-organisational relationships (Kagermann, Wahlster and Helbig 2013; Millien and George 2017; BDI Noerr 2015; Prause 2015).

One could argue that closing this gap in the literature is critical in order to provide evidence of the role and importance of IPS at the different phases of implementation of I4.0, as well as for each phase of the life cycle and for the different types of partners and collaborators.

2.4.5 Intellectual Property Key Findings

After conducting the above literature review and having critically assessed the aforementioned materials, the following conclusions can be made:

i- The literature demonstrates the paramount role of IP in the functioning of inter-organisational collaborative and knowledge exchange initiatives (Chesbrough and Crowther 2006; Hertzfeld, Link and Vonortas 2006; Teece and Pisano 2007; Lichtenthaler 2010). Nevertheless, many areas, such as the relationship between the different types of IP (formal and informal) at different stages of such initiatives, are still open and considered a topic for debate (van de Vrande et al. 2010).

ii- The literature lacks a comprehensive account of the implications of I4.0 developments on organisational structures, collaborations and IPSs supporting these business relationships (Kagermann, Wahlster and Helbig 2013; Brettel et al. 2014; Emmrich et al. 2015).

iii- The literature is unclear on the role of IP in the context of the new BMs and highly collaborative inter-organisational relations emanating from the implementation of I4.0 across the value chains where large amounts of information and knowledge will be exchanged on unprecedented scales.

iv- The IP literature focuses on the protection of IP in relation to patents (Boldrin and Levine 2013; Moser 2013). Patents are just one of the potential protection mechanisms available for manufacturers. The literature lacks an empirical account of other mechanisms for appropriating value in the manufacturing value chain such as other formal methods (trademarks, copyrights, and design rights) and informal methods (secrecy, lead time, contractual agreements, and complexity).

v- The literature does not account for an empirical analysis of the relationship between appropriability mechanisms (formal and informal), highly connected manufacturing value chains (I4.0) and the manufacturers' IPSs.

It is argued that the literature regarding appropriability lacks a framework or tool that can be applied to evaluate a particular appropriability regime accounting for the various businesses positioned within a given value chain that could be utilised in order to address challenges and opportunities such as those faced by the automotive manufacturers entering the I4.0 horizontally connected value chains.

The literature review presented above provides evidence that there is a gap regarding a detailed analysis of the impact of I4.0 horizontal integration on manufacturing businesses, BMs and their respective IPSs, paying special attention to the differences and similarities of each BM (current or new) and the position of a given business within the manufacturing value chain.

2.5. Chapter 2 Conclusion

Industry 4.0 is a relatively new topic in the literature, representing a new paradigm. The literature review for the purposes of this research is multidisciplinary and includes over 300 selected papers across three areas (I4.0, BMs and IPS).

This chapter has critically evaluated the literature and identified the relevant gaps to be addressed by this research. Firstly, there is a gap in the literature regarding an empirical and comprehensive account of I4.0, especially in relation to the horizontal integration of manufacturing value chains, as well as its implications for manufacturing businesses, their BMs and value appropriation driven by intellectual property strategies.

Secondly, this chapter also shows that there is a gap in the business model literature regarding empirical evidence demonstrating the impact of Industry 4.0 on manufacturers' business models adopting this new paradigm. Such study could provide the basis for a business strategy, business model and IP strategy framework to be deployed in order to support academia and practice to account for the impact of Industry 4.0 on current manufacturing business models in the face of the horizontal integration of businesses within the value chain.

Thirdly, it is argued that the literature review demonstrates that there is a gap regarding a detailed analysis of the impact of I4.0 horizontal integration on manufacturing businesses, business models and their respective IP strategies, with special attention to differences and similarities of each BM (current and/or new) and the position of the business within the manufacturing value chain and the extent to which the appropriation regime for manufacturers will be impacted. Thus, it is important to understand how IP strategies can be adjusted to protect innovation, and to boost the manufacturer's performance in the I4.0 horizontally integrated value chains.

The next chapter will describe how this research will address the gaps found in the literature in order to make an original contribution to knowledge and to support automotive manufacturing businesses to address the challenges and opportunities faced in this new paradigm.

3. Chapter 3 – Research Methodology

3.1. Introduction

The term methodology is used in this context to describe the philosophical and technical aspects of a research project. From a philosophical point of view, it seeks to explain the reasoning regarding a given approach to investigating the world in order to improve our understanding of it (Sayer 1992). From a practical point of view, it focuses on exploring the various technical methods available in order to select the most appropriate tools and techniques for a given study (Bruce and Yearley 2006). Methodology can be classified as the science of research methods. This area typically covers both the technical and philosophical stances related to the reasoning of the study.

The key function of a research method is to allow the researcher to perform research activities in a robust, reliable and scientific manner. Furthermore, the research methodology should also set out the required tools, techniques and mechanisms to be deployed in order to appropriately achieve the research aims and objectives (Singh 2006).

In Chapter 1, the subject (I4.0) and the dynamics of this research (the impact on business models (BMs) and Intellectual property strategies (IPSs)) were examined with a critical perspective on 'What is the impact on I4.0 of Manufacturing BM and IPS?'. Chapter 1 also points out that the change in paradigm triggered by I4.0, and its risks and opportunities, are not well understood as most of the 'hype' about the phenomenon focuses on technical aspects (technology and engineering), rather than the socio-economic aspects (impact on businesses, society and the wider economy).

Chapter 2 focused on the literature review, providing a theoretical background and context to understanding the three key areas of this research. Firstly, it provides an assessment of I4.0 and explores the key factors affecting, and likely to affect, manufacturing businesses and their BMs and IPSs. Next, the BMs literature was critically assessed to review the changes taking place and how such changes are affecting individual businesses.

The final theme in Chapter 2 assessed the implications of the horizontal integration of businesses in the manufacturing value chain for IPS and value appropriation. IPS in this context is viewed as critical in linking business strategy, business models and value appropriation in the new inter-organisational relationships emanating from I4.0.

In this chapter, the researcher explores the research methodology utilising the Research Onion Model as presented by Saunders, Lewis and Thornhill (2012) and shown below (Figure 8). As such, the chapter will begin by presenting the philosophical stance, the research approach, the strategy and design. This will include an explanation of the research methods utilised, the shift in the researcher's perspectives and outlook that took place during the research activities, and the reasoning for choosing case study as the method for performing this research's qualitative analysis of in-depth interviews and the secondary data.

The following figure demonstrates the Research Onion approach utilised by the researcher.

FIGURE 8 - RESEARCH ONION (SAUNDERS, LEWIS AND THORNHILL, 2012)

The following figure demonstrates the structure of this chapter.

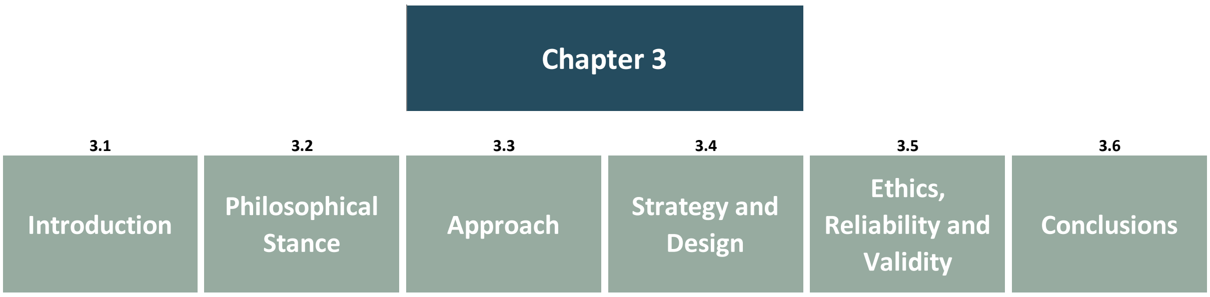

FIGURE 9 - CHAPTER 3 STRUCTURE

3.2. The Philosophical Stance

3.2.1 The Ontological Perspective

Ontology and epistemology are the two research philosophy perspectives. Ontology, 'the study of being', is a belief system that reflects an individual's interpretation of what constitutes a fact; thus, it deals with the nature of reality. Its essence is to ask the central question of whether the social entities or phenomena in question ought to be perceived objectively or subjectively.

The two main ontological perspectives are objectivism (or positivism) and subjectivism (or constructionism). Each can be defined as follows:

I - Objectivism / Positivism portrays the position that social entities exist in reality external to social actors concerned with their existence (Saunders, Lewis and Thornhill 2012). This stance has also been defined as an ontological position that asserts that social phenomena and their meanings have an existence that is independent of social actors (Bryman 2012).

II – Subjectivism / Constructionism (also known as interpretivism), on the contrary, views the social phenomena as being created from perceptions and resulting actions of social actors concerned with its existence. This stance can also be defined as an ontological position which asserts that social phenomena and their meanings are continually being accomplished by social actors (Bryman 2012).

The following table illustrates the ontology of four major research philosophies in social sciences.

Research philosophy	Ontology: the researcher's view of the nature of reality
Pragmatism	External, multiple views chosen to best enable answering of research question
Positivism	External, objective and independent of social actors
Interpretivism	Socially constructed, subjective, may change, multiple
Realism	Is objective. Exists independently of human thoughts and beliefs or knowledge of their existence (realist), but is interpreted through social conditioning (critical realist)

TABLE 2 - RESEARCH PHILOSOPHIES – ADAPTED FROM SAUNDERS, LEWIS AND THORNHILL (2012)

The selection of the ontological perspective at the beginning of the research process is paramount to the research design as it influences the approaches and strategies deployed by the researcher throughout the project.

The following flow figure demonstrates the interrelations between the ontological choice and the selection of different methodological elements such as the research approach, strategy, data collection and analysis methods.

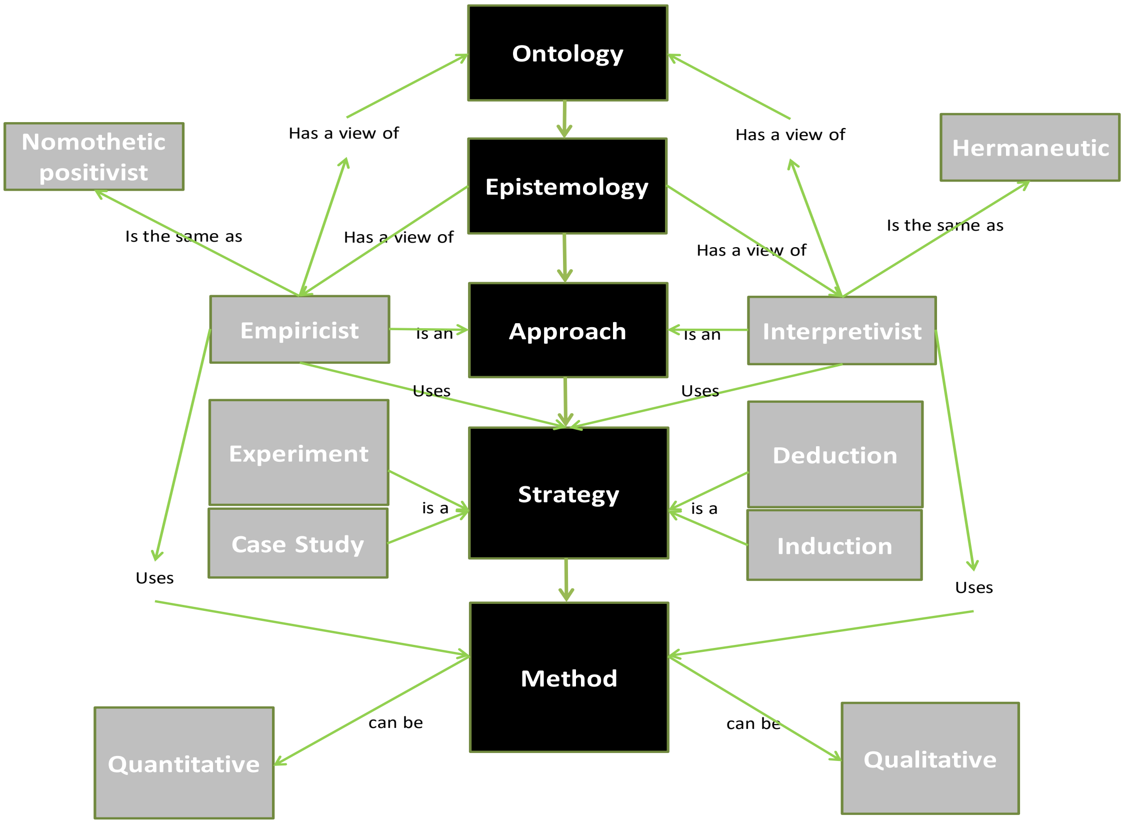

FIGURE 10 - IMPACT OF ONTOLOGICAL CHOICES – ADAPTED FROM SAUNDERS, LEWIS AND THORNHILL (2012)

After careful consideration of the different stances in the context of the subject of this study the researcher has selected the interpretivism/constructivism paradigm, as it supports the exploration of the phenomenon of I4.0 based on the perceptions and actions of social actors, in this case the manufacturers represented by the interviewees who participated in this study.

These social actors (the businesses participating in the study) are concerned with I4.0 horizontal integration and its existence in order to assess the impact of I4.0 on their businesses. The researcher, on the other hand, is concerned with collecting and analysing data in order to provide a contribution by presenting a reality that will be 'socially constructed'.

This choice of paradigm is justified as it is argued that such reality ('What is I4.0?' and 'How does I4.0 impact manufacturing businesses?') does not exist independently of the businesses participating in the studies and the researcher and the phenomenon central to the study.

The next few sections will discuss the impact of the selected ontology on the research design.

3.2.2 The Epistemological Perspective

According to Easterby-Smith, Thorpe and Jackson (2008), epistemology is a philosophical approach to knowledge which seeks to explain and justify the assumptions made by the researcher in order to create the appropriate theoretical perspective and select the methodology to be deployed in a research project.

Epistemology has also been defined as a “paradigm” (Guba and Lincoln 1994), “methodology” (Neuman 2003), or “worldview” (Creswell 2009). Whichever the definition, the epistemological perspective is the foundation of the entire research and will influence the subsequent theoretical perspectives and methodologies relied upon for data collection throughout the study (Gray 2009).

It is argued that objectivism, constructivism and subjectivism form the key epistemological stances (Crotty 1998). In this context, objectivism aims at describing meaning in a completely independent form, distinct from the subject, proving a version of the truth that emanates from the object of the research itself. This stance holds that the truth in all accounts is available “out there” waiting to be discovered. On the other hand, constructivism focuses on deriving a meaning which emanates from the relationship between the subject and the object. Thus, meaning only exists via this interaction between the two parts. Also, in the subjectivist stance the meaning is generated by the imposition of the subject on the object. As such, the truth is imported via an external factor outside the relationship between the subject and the object.

This research project aims to create theoretical and practical knowledge of complex areas (i.e. I4.0, BM Theory, and IPS in the context of the automotive manufacturing industry in the UK). As such, the research is primarily based on constructivism, as the meaning is constructed apart from the relationship between the subject (“researcher”) and the objects (“areas of research”).

Although the researcher has an "insider" perspective due to experience in the area and being employed by an automotive manufacturing company undergoing the transformations of the fourth industrial revolution, the researcher aims to act as an agent who interprets the data collected in respect of the impact of I4.0 on the businesses participating in the study, and provide a theory to be utilised in respect of the object of study (Guba 1990), in this case I4.0 horizontal integration.

3.2.3 The "Insider" Perspective

Most of the research activities related to this project took place at the Institute for Advanced Manufacturing and Engineering (AME), which is physically located at the Unipart Manufacturing Plant in Coventry in the UK. AME is a collaboration between Coventry University and Unipart Manufacturing, a large tier 1 automotive manufacturing company based in the United Kingdom.

Prior to the initiation of this project, the researcher had worked for Unipart Manufacturing for over five years, in a number of roles relating to organisational design and value chain design and improvement. These roles included positions such as Continuous Improvement Engineer, Solutions Design Manager, Solutions and Business Improvement Manager, Senior Digital Champion for Manufacturing and Innovation and Digital Director.

In the year preceding this research, the researcher had been involved in a number of digital transformation activities, both within Unipart and in its customer base. Furthermore, during the course of the first two years of this research, the researcher continued to provide support to set the organisational, intellectual property strategy and business system design for a new joint venture between Unipart Manufacturing and a well-known motorsport and engineering company, which aimed at utilising Industry 4.0 tools to support the manufacturing of battery packs for high-performance electric vehicles.

This level of prior involvement has provided a unique opportunity to get extremely close to the day-to-day operation of the business, a desirable prerequisite to study strategising (Balogun, Huff, and Johnson 2003). Furthermore, it has also supported the research as it gave access to various participants who, due to prior relationships, were inclined to provide good-quality data (Hammersley and Atkinson 2007). This position as an 'insider' also accelerated the process of understanding the manufacturing industry and its dynamics (Saunders, Lewis and Thornhill 2012), a feature said to enable high-quality analysis of raw data (Yin 2018). This is particularly important in interpretive case study research, where findings are influenced by the researcher's own experience and background (Stake 1995).

The researcher's past training in Law and Intellectual Property, combined with his experience in the manufacturing industry and his long-term engagement with Unipart provided the author with what Lincoln & Guba (1985) describe as a unique perspective of the three key areas of this research (Industry 4.0, business models and intellectual property strategies). Furthermore, it also provided him with a better understanding of the 'technical language' (Giddens 1993: 170) used in the industry. Technical language refers to expressions and jargon used specifically in the context of the phenomena under study, which could be misunderstood by someone who is not familiar with the context (Giddens 1993).

This level of previous engagement with the research setting could give rise to some challenges. For example, there is a risk that, due to the familiarity with the businesses being observed, the researcher could "seriously misunderstand the behaviour observed" (Hammersley and Atkinson 2007: 87). Being too close to interesting phenomena can also be problematic because phenomena should always be seen within their wider contexts (Hammersley 1993). Another challenge is becoming too friendly with participants (Hammersley and Atkinson 2007).

These risks were addressed by the researcher by taking three key steps. Firstly, an 'emic' approach to data analysis (Silverman 1993) was implemented, whereby first-level codes emerged from the raw data. Secondly, method triangulation and source triangulation were utilised to validate the findings (Patton 1987 and Yin 2018). Finally, the researcher interviewed a number of participants employed by different companies (suppliers, partners and customers), always maintaining an audit trail via the research log in order to account for the researcher's prior knowledge (Lincoln and Guba 1985). Having explored the researcher's philosophical stance, attention will now turn to the research approach.

3.3. Approach

3.3.1 The Research Approach

Having identified the researcher's philosophical stance, an appropriate approach must be selected. As suggested by Gray (2009), induction and deduction are the two key approaches in a research study, and they go hand in hand with the researcher's logic.

The inductive process focuses on data collection and analysis with the aim of uncovering patterns and ascertaining generalisations, relationships and theories. It requires a critical approach in order to uncover the emerging patterns and locate their significance within the theory relevant to the research (Bryman 2008). On the other hand, the deductive approach focuses on testing a hypothesis or theory, in order to assess the research concept. As such, it requires a theory or concept that can either be proved or disproved in respect of the hypothesis (Gray 2009).

Researchers tend to rely on qualitative methods for inductive studies (interviews, observations and case studies) and quantitative methods (surveys and statistical analysis) for deductive studies (Creswell 2009 and Kumar 2011).

Given the novel and uncertain nature of I4.0, which is one of the motivating factors of this study, and the multidisciplinary approach taken by the researcher through the combination of I4.0, BMS and IPS, it is argued that a deductive approach that clearly formulated a hypothesis would be less effective in achieving the objectives of the study and answering the research questions.

As such, the researcher adopted an inductive approach, so the information regarding the development of I4.0, and the context of BM and IPS, was explored and compiled through interviews, contract analysis and case studies focused on identifying the impact of I4.0 implementation on manufacturing businesses.

Furthermore, the researcher considered that the inductive approach was critical to shedding light on the emerging patterns in response to the new horizontally integrated manufacturing value chains. This in turn was an important step in achieving one of the practical objectives of this research, which was to provide a tool to support the adaptation of current BMs and IPSs in manufacturing, the reduction of risks and maximisation of value for manufacturing businesses.

3.3.2 The Research Purpose

Research purposes can typically be categorised into three types according to Robson (2011); I) Exploratory; II) Descriptive; and III) Explanatory.

An exploratory research enquiry aims to provide answers to ‘What?’ questions, by exploring a mostly novel and uncharted socio-economic phenomenon (Saunders, Lewis and Thornhill 2012). As such, due to its novelty, quantitative data is most likely to be limited and, therefore, qualitative research techniques are often more appropriate for an exploratory study (Neuman 2003).

The second category is descriptive and seeks to answer ‘How?’ and ‘Who?’ questions, by describing the relationship between a person, an event or a situation in order to provide an understanding of such a phenomenon (Gray 2009).

The last category, explanatory research, seeks to answer ‘Why?’ questions in order to explain the source of a phenomenon (Yin 2018). The key distinction between descriptive and explanatory is that the latter is associated with quantitative research (Gray 2009).

It is argued that this research is ‘exploratory’ as it primarily asks ‘What?’ questions, but the study also extends to the explanation of the consequences of the transformation and the impact on manufacturing BMs and IPs. Furthermore, it focuses on the creation of a set of constructs aimed at providing a method or framework for the analysis and evaluation of the phenomenon of I4.0 in the context of BMs and IPSs for manufacturing businesses (Neuman 2003).

In doing so, the researcher seeks to explore and become familiar with facts, settings and concerns emanating from the implementation of I4.0 in the manufacturing value chain. Equipped with these 'data points' the study focuses on creating a model to assess the impact on manufacturing businesses, as such model supports the formulation of the research questions and the determination of the research data collection and analysis methods.

In certain parts of this study the researcher also explores the evaluation studies and attempts to test the theory (i.e. assumptions regarding the positive impact of I4.0 on manufacturing businesses), which is on the descriptive side of the research spectrum. It is argued that this crossover is common in regard to research studies attempting to answer multiple questions as in this study, as each of the questions may seek to achieve a different objective (Gray 2009).

Having explored the research approach, attention now turns to the research strategy and design.

3.4. The Research Strategy and Design

According to Saunders, Lewis and Thornhill (2012), research strategy is the definition of how the researcher will perform the research. The strategy typically includes a number of different approaches which will be designed in order to achieve the research objectives. These approaches may include, for example, a literature review, experimental research, case studies and surveys. The following paragraphs will explore the most common approaches to research strategy and describe the strategy selected for this research.

The first strategy to be explored is known as experimental research. This research method aims at establishing a research process focused on examining the outcomes of a given experiment and verifying such outcomes in contrast with the expected results (Saunders, Lewis and Thornhill 2012).

Such an approach is typically used across a wide spectrum of research areas, but it is mainly focused on research with a limited number of factors which are cross-examined and assessed against the expected results (Saunders, Lewis and Thornhill 2012).

Another research strategy to be discussed is known as action research, which is characterised by Bryman (2012) as a practical method to deal with a very specific research question or problem. It typically focuses on examining different practices in order to establish the best practices or approaches. According to Wiles, Crow and Pain (2011) this type of strategy is typically utilised by researchers in teaching or nursing, to understand the various ways of improving their professional practices.

Case study research is another very popular strategy which is defined by Bryman and Bell (2012) as the assessment of a specific entity in order to establish its characteristics and draw general conclusions. This research type offers an insight into the specific nature of a given entity and supports the assessment of the importance of a culture and context in a particular case; the comparison of different cases can also be helpful (Silverman 2013). This form of research is effective in comparing the practices and experiences of multiple companies or comparing the effect of a given phenomenon in different contexts (Bryman and Bell 2011).

Also very well known, grounded theory is explained by May (2011) as a qualitative methodology based on an inductive approach aimed at deriving patterns from the study data. In this case, all the interview data, for example, is transcribed, coded and grouped according to the similar themes and common indicators derived from the data itself. Thus, the conclusions from such research are derived essentially from the gathered data itself, rather than contrasting and verifying its similarity with pre-existing findings (Flick 2018). This strategy is typically utilised in social science research exploring new phenomena (Bryman 2012).

A survey-based research strategy tends to be used in quantitative studies, which involves a representative sample of the population that is the subject of the research (Bryman and Bell 2011). This approach typically produces quantitative data that is then analysed in order to derive empirical conclusions. Surveys are commonly used to assess causal variables between diverse data sets.

There are a number of other research strategies, such as ethnography, which involves the observation of people and the assessment of their cultural interactions and meanings (Bryman 2012), and archival research, which is conducted from existing historical materials (Flick 2018). Nevertheless, these research strategies are not well suited to the purposes of this particular research, as the study is concerned with neither historical materials nor ethnographic characteristics of a particular culture.

After reviewing the available research strategies the researcher selected case study as the overarching approach for this study. It is argued that utilising a case study strategy will benefit this research in achieving the set objectives and answering the research questions discussed in Chapter 1, as the case study approach is an ideal strategy for situations where the subject of the research needs to be studied in its environment, relying on multiple sources of data to compare and contrast different manufacturers in the value chain under varying levels of I4.0 implementation.

Furthermore, by utilising multiple case studies the researcher will be able to compare alternative strategies for value creation and capture through the current intellectual property strategies deployed by different businesses in the value chain and enhance the understanding of a complex network of relationships created by I4.0.

3.4.1 The Research Strategy

In order to formulate an appropriate research strategy the researcher has relied on the key aspects as explored by Yin (2018, p. 3-13), namely: i) The nature and form of the study question; ii) Demonstrating the reliability, replicability and validity; iii) Defining a sufficient amount of case studies; iv) Collecting, processing and analysing a data set from various sources relevant to case studies; and v) Reaching a representative number of stakeholders. Each of these factors will be discussed in turn.

i- The nature and the form of the study question

'What is the impact of horizontal integration on current manufacturing business models and intellectual property strategies and how these can be changed to address risks and opportunities?'

In approaching the main research question, it was unlikely that the researcher would find a single event in a single set of relationships between a manufacturer and a supplier which was able to provide the data to answer the question. Instead, the research had to explore the relationships between a manufacturer and its value chain and the relationships across multiple events and processes and their perceptions of the impact of horizontal integration.

The impact of horizontal integration in manufacturers' IPS can be studied in the context of real-life projects demonstrating the current practices regarding collaboration at the research and development, as well as production stages. These projects would provide the researcher with a wide range of evidence including interviews, documents and artefacts which demonstrated the relationship between the manufacturer and its value chain. This opportunity to collect data from various sources in the context of a case study provides the chance to triangulate the data collection to cross-check the research findings.

These complex relationships and the settings in which they take place in the real world are very difficult to control when the researcher is trying to compare and contrast them in order to focus on a defined number of variables related to the impact of horizontal integration on manufacturing businesses' IPS. The value chain relationships in this study are influenced by many variables such as technology, market forces, personal motivations internal and external politics, all of which are beyond the scope of this research and the control of the researcher.

The researcher has considered the common criticisms of case study research strategy such as those highlighted by Myers (2009), who used terms like 'validity' and 'reliability', which "imply an objective reality independent of social reality" (p. 78). Other concerns have also been explored by Yin (2018, p. 15), who mentioned issues related to generalisation of findings and the large amount of time taken to produce case studies.

In line with these criticisms, the researcher was aware of the significant challenges arising from the research context and the practicalities of exploring such a complex setting, including:

ii- Demonstrating the reliability, replicability and validity

In order to arrive at reliable, valid and replicable findings the study should provide more than a single case study and involve more than a single organisation. This approach was based on the logic that "the evidence from multiple cases is often considered more compelling, and the overall study is therefore regarded as being more robust" (Yin, 2018, p. 53).

iii- Defining a sufficient amount of case studies

The researcher also considered the amount of case studies necessary to demonstrate the most common types of relationships and the scenarios required to demonstrate the quality and validity of the data and the subsequent findings.

iv- Collecting, processing and analysing a data set from various sources relevant to the case studies.

The researcher sought to create a method for collecting and processing the data in order to minimise the effort required by standardising the note-taking methods, utilising digital recorders, using bespoke software created in the programming language Python to achieve a semi-automatic transcript and using a coding software to analyse and code the interview data.

v- Reaching a representative number of stakeholders

The researcher sought to select a number of businesses across the value chains and the stakeholders within those businesses in order to represent the real-life practices related to relationships between these organisations.

Having recognised the traditional prejudices related to case study research, the researcher has taken every step to ensure that the practical issues did not affect the rigour and relevance of the data collection or the research findings. In doing so, the researcher emphasised the validity of the methodological decisions made during the design of the research.

The researcher recognises the key benefit of case study strategy and its ability to allow multiple data sources to be collected and analysed in the context of a phenomenon. Also, that case study strategy enables the capture and presentation of the complexities emanating from the real-world relationships being affected by the implementation of I4.0 horizontal integration in the automotive manufacturing industry in the UK.

Having identified the research strategy, attention will now turn to the particular research design, starting with a discussion of the research method.

3.4.2 The Research Design

3.4.2.1 Qualitative, Quantitative or Mixed Methods

Research can be classified in many ways. Nevertheless, there is a major distinction between quantitative and qualitative research (Flick 2009 and Saunders, Lewis and Thornhill 2012). The former emanates from natural sciences and is also known as “hypothesis testing” research. It relies on procedures that contribute to the scientific knowledge base by theory testing. It includes well-accepted research methods such as surveys, experiments and formal and numerical methods (Saunders, Lewis and Thornhill 2012).

Qualitative research is based primarily on constructivist perspectives, participatory perspectives or a mix of both (Creswell 2009). It utilises ‘soft’ data in order to accommodate the researcher’s aims, and emphasises the relationship between theory and research. Thus, emphasis is placed on the generation of theories, using research methods like grounded theory, ethnography, observations and case studies (Flick 2009). Both research types have their advantages and limitations (Hanson and Grimmer 2007) and, generally, the key advantage of each method is that the knowledge cannot be gained by the other method.

Due to the chosen philosophical stance, research approach and strategy, the utilisation of a qualitative method approach was selected as the most suitable method to collect the data and increase the confidence in the research results. It also sheds light on different dimensions of the problem to be considered (Bryman and Bell 2011), and is a valuable asset in analysing a complex and multifaceted subject such as I4.0. Having discussed the research method, attention will now turn to explaining the data collection design.

3.4.2.2 Data Collection Design

After the selection of the case study research strategy, the researcher carefully considered the design of a particular set of case studies to ensure that the objectives of this research were satisfied.

As discussed above (section 3.4.1), the case study strategy is flexible in the sense that it incorporates data from various sources and of different types. With this advantage in mind, the researcher has evaluated the most popular data collection methods and selected a number of these methods in order to improve the reliability of the research by triangulating and validating the data collected and the findings.

The choice of data collection methods was based on a literature review of data collection methods, which focused on studies in the field of Information and Business Management. A study that was very informative and provided an extensive content analysis of applied research data collection methods over a period of more than a decade and pointed out the most widely utilised methods, key attributes, advantages and disadvantages was carried out by Palvia, Pinjani and Sibley (2007). The authors argue that the survey method is still the prominent data collection methodology in information systems, however in-depth interviews and case studies have been also used frequently, particularly in order to investigate complex relationships via business management lenses as in the case of this research,

The selected methods were based on the areas, aims and the objectives of the research, as well as the literature analysis. The following table was created to demonstrate the data capture methods used to support the overall research objectives and answer the research questions.

Data Collection Method	Data Source			
Literature Review	Industry 4.0	Business Models	Intellectual Property	Conclusions
Key Informant Interviews	Engineering Consultancy	IP & Legal Services	Manufacturing Large	Manufacturing SMEs
Contractual Analysis	Model Agreements	Collaboration Agreements	Customer/Supplier Agreement	NDA Agreements
In-depth Interviews	Manufacturing OEMs	Tier 1 Suppliers	Technology Developers	Research Institutions
Case Studies	Base Line Case Study	Case Study 1	Case Study 2	Case Study 3

TABLE 3 - DATA COLLECTION STRATEGY SUMMARY

3.4.2.3 Data Triangulation

As demonstrated in the table above, the data collection methods contributing to the three case studies in this research include:

i- Literature reviews to understand the phenomenon of I4.0, business model theories to understand the impact of such phenomenon and the legal implications of the impact on business models;

ii- Key informant and exploratory interviews to explore the context of I4.0 and its benefits and risks;

iii- Contractual analysis of current model agreements, collaboration agreements, joint venture agreements, non-disclosure agreements and supply agreements deployed by manufacturing businesses in order to identify any potential issues regarding the implementation of I4.0;

iv- In-depth interviews with experts in order to establish the wider context and improve knowledge in the area.

These methods were chosen with the aim of providing a varied perspective into this difficult-to-encapsulate subject. It also aims to improve the study's validity by utilising research triangulation strategies in order to attempt to generate and validate the research findings whilst ensuring the study's reliability.

As such, with the deployment of data collection from different sources, the researcher aims to improve the confidence levels and the reliability of the results. This enables the study to provide an increased level of certainty in exploring the complex and uncertain areas of this research (I4.0, BM and IP strategies), all of which – as discussed in Chapter 2 – are subject to disagreements as to their definitions and applications.

During the first stage of the project, triangulation is performed via multiple sources of information to validate the assumptions and conclusions from each source in order to ensure the research questions are valid and the research methodology is appropriate to achieve its aims and objectives.

The first stage of triangulation cross-examined and combined: i) An in-depth literature review of the three main areas of research, namely: a) Industry 4.0; b) Business model theory; and c) Intellectual property strategies, with ii) Key informant interviews, current best practice in the relevant areas and iii) Qualitative data from current contractual agreements utilised by automotive manufacturers and their value chains. This selection of multiple sources, in addition to the benefit of improving the reliability of any conclusions, also contributes to the researcher's knowledge and understanding of the research question, impact and potential contribution to both academic and practical spheres.

In the second stage of research, the triangulation cross-examined and combined the literature analysis including in-depth strengths, weaknesses and gap analysis of the three main areas of research. Such triangulation results in critical and cumulative knowledge and enhances the quality of the research.

In the third stage, the triangulation took place in the form of testing the findings from the previous two stages by performing: i) in-depth interviews to validate the gaps and potential solutions; and ii) case studies to demonstrate the findings in terms of their application, suitability and potential impact. This enabled the researcher to refine the proposed framework for the analysis of the impacts of I4.0 horizontal integration on business IPS and increase the confidence level in the framework.

In the final stage, triangulation was performed in order to validate the proposed framework and make the final improvements before the completion of the thesis. In this stage the researcher cross-examined: i) in-depth interviews with subject area experts to validate the efficacy and application of the proposed framework, with ii) case studies where the proposed framework was applied and compared with the previous best practice in order to test its efficacy and validate its application to the real world.

In conclusion, the data triangulation method developed allowed cross-checking of the validity, efficacy and applicability of the research findings and recommendations. Having explored the chosen research strategy and design, attention now turns to ethics.

3.5. Ethics, Reliability, Validity and Limitations

3.5.1 Ethics

A careful consideration of research ethics is imperative for a good research project, as well as being essential for the credibility of the researcher, the supervisory team and the university. As such, it is important to state that this research project closely observed Coventry University's research ethics process and procedures.

Furthermore, the researcher has read all the recommended ethics information available at the Coventry University Ethics portal in order to obtain the required knowledge of the ethical implications of a research project and its impact on all parties involved. In line with the ethics guidance, all appropriate measures were taken to ensure that all parties involved at any stage of the research were fully aware of the procedures, including but not limited to the fact that they could withdraw their participation at any time.

Participant information forms and consent forms were utilised as attached in Appendices 1 and 3, and all participants were assured that their information would be kept strictly confidential and anonymised, on the secure drives of the university, only for the specified duration of the project, and that upon the expiry of the project duration, all data will be destroyed.

Due to the specifics of this project, the research was assessed via the ethics application process to be medium-risk. All the necessary steps and safeguards were adhered to, including risk assessments. The ethics application was approved by the Coventry University Ethics Team.

3.5.2 Reliability

The researcher has considered the reliability and validity of this research throughout the entire project. As mentioned in the previous section, in order to increase reliability, multiple data collection methods were utilised and triangulated. Additionally, the external validity of the research was critical to the researcher as the project seeks to provide recommendations for practical application for manufacturing companies. As such, an evaluation of the research framework was conducted to test it in a practical application in the selected case studies.

The reliability of a research study is determined by the extent to which the research can be replicated with similar results when performed independently (Bryman 2008), thus minimising any concerns and risks regarding errors and bias by the particular researcher (Yin 2018).

It is argued by Neuman (2003) that as reliability is mostly associated with quantitative data principles, it should not be applied to qualitative research, especially in the case of organic data capture which changes during the entire research.

The reliability of a qualitative research study can be increased by the use of triangulation techniques, which can be deployed throughout the research investigation, methodology and data capture, as argued by Dellinger and Leech (2007).

The triangulation already described in this chapter (section 3.4.2.3) increases the reliability and validity of the research by addressing the limitations of individual methods of data collection and was utilised in all phases of this research.

3.5.3 Validity

The research validity correlates to its reliability. However, the latter is focused on the appropriate consistency of the data and aimed at ensuring that the research provides a realistic interpretation of the subject of study (Neuman 2003).

Research validity also originated as part of the quantitative method of research, and there are arguments as to whether it should be applied to qualitative methods of research (Guba and Lincoln 1994; Dellinger and Leech 2007). Nevertheless, this research has adopted both internal and external validity as suggested in the literature on qualitative research (Gray 2009; Yin 2018).

Research validity can be split into internal and external aspects. Internal validity focuses on ensuring that there are no issues with the particular research design and the data analysis, thus attempting to prevent methodological errors by the researcher (Neuman 2003; Bryman 2008). The external aspect of validity focuses on the assumptions regarding the generalisation of the research, as the sample sizes are typically limited in qualitative research studies and as such an appropriate sample for the particular research should be utilised.

It is difficult to establish the recommended sample size, as the literature suggests that an effective sample for interviews can vary between two and 25 participants (Beitin 2012). Furthermore, there are a number of papers that offer guidance on selecting the sample, but not the most appropriate size (Gray 2009). Therefore, it can be argued that the effectiveness of the sample size will be directly dependent on the particular study (Bryman 2008).

As described in the reliability section, the internal validity was improved via the 10 key informant interviews with subject area experts, which provided an opportunity to increase the validity of the models and frameworks used during the research by subjecting them to the interviewees' scrutiny. Furthermore, the external validity was also improved via a case study where the findings and the proposed framework to address the risks and opportunities emanating from the implementation of I4.0 were applied and compared with the previous best practice in order to test its efficacy and validate its application to the real world.

3.6. Chapter 3 Conclusion

There is no doubt that selecting the appropriate methodology is paramount to achieving the research aims and objectives and ensuring that the research question is satisfactorily answered. The objective of this chapter was to explore the chosen research methodology and explain the researcher's philosophical stance and the approach and strategies of this research. As such, this chapter is core to understanding how the rest of this thesis presented in the following chapters has been conducted.

This chapter has presented the rationale for the research methodology by following the Research Onion Model as proposed by Saunders, Lewis and Thornhill (2012). Furthermore, the research approach was presented as inductive, which is suitable in combination with the proposed research framework and research purpose. In addition, the strategy and design were laid out, presenting the case study strategy, the mixed-methods research and describing the triangulation strategy to be employed.

Finally, this chapter also explored in detail the data collection and analysis methods, as well as the concerns regarding ethics, reliability and validity.

In conclusion, this chapter covered the research methodology for this study, the researcher's perspectives and expectations during the period of this project and the reasoning for selecting the case study method as the key research technique to gather and present the insights acquired during the research via a qualitative analysis of in-depth interviews and secondary data.

The next chapter will explore the data collected using the selected methodology, the data interpretation and findings of the key informant interviews, in-depth interviews and the case studies.

4. Chapter 4 – Data Collection

4.1. Introduction

Following on from the previous chapter on research methodology, this chapter will explore the processes and procedures utilised to collect the primary and secondary data in order to answer the research questions as presented in Chapter 1.

The literature review shows the gap regarding the impact of I4.0 implementation on manufacturing companies' business models and intellectual property strategies as highlighted in the conclusion of Chapter 2. The data collection phase of this project has focused on collecting data from businesses and individuals with appropriate knowledge and experience to make a contribution by addressing this gap in knowledge in relation to both theory and practice.

This chapter begins with a description of the case study selection in section 4.2, where the justification for the case studies was explored. Section 4.3 explores the individual case studies and section 4.4 provides the actual data collection methods and processes. Finally, section 4.5 provides a description of how the data was aggregated into the case studies, and section 4.6 presents a conclusion to the data collection chapter.

The following figure shows the structure of Chapter 4.

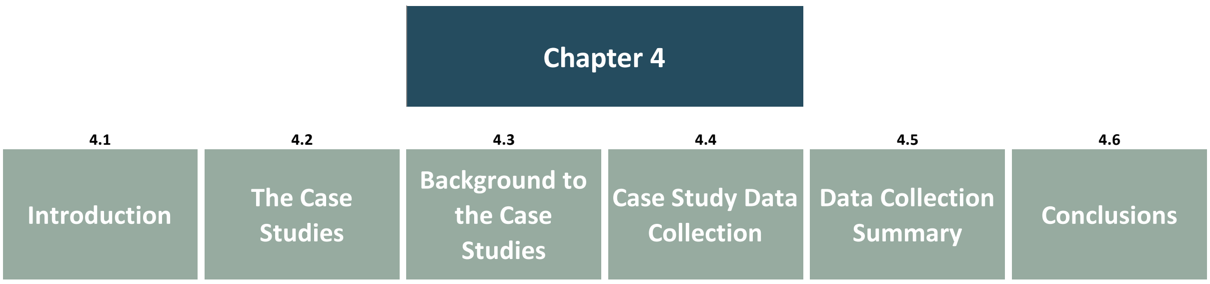

FIGURE 11 - CHAPTER 4 STRUCTURE

4.2. The Case Studies

As discussed in Chapter 3, the case study approach is a very popular research method in the area of business and strategy, as case studies have various advantages, like the potential for in-depth insights into a problem in its context. In this research, case studies have been selected due to the ability to support data collection and analysis within the context of a particular phenomenon, integrating multiple data sources and enriching data analysis.

Furthermore, this approach supports the capture and presentation of complexities emanating from real-world scenarios, enabling the study of the object in the wider context and at an increased level of detail. After the selection of the case study research strategy, the researcher carefully considered the design of a particular set of case studies to ensure that the objectives of this research were achieved.

The four case studies in which the data was collected and aggregated have been designed in order to answer the 'how' or 'why' questions and to provide a view of the object of study, which emphasises the contexts of real-world scenarios and events, as well as to answer the 'what' or 'who' questions and aggregate the data collected from the interviews, thus providing further context to the research data. The following paragraphs will discuss the case studies selected for this research.

4.2.1 Case Study Selection

In the typical value chain there are many types of relationship, varying from transactional relationships at one end of the scale all the way to strategic relationships at the other. These types of relationships can also differ in multiple factors such as duration, expectations, liabilities, level of interaction, goals, benefits and risks.

What can also be noticed is that transactional relationships are more prominent in the traditional vertical value chains where supplier and customer relationships are negotiated at an arm’s length. On the other hand, strategic relationships are associated with horizontal value chains where businesses seek to leverage each other’s expertise for mutual benefit.

It is argued that manufacturers in the automotive value chain are involved in both types of relationships during the life cycle of a product, service or technology. As an example, the product development of automotive vehicles including their component manufacturing processes is a very complex process that involves many businesses across the value chain. These businesses normally start the development process with strategic collaboration projects where they work to create future products or processes. Once this phase of the life cycle is completed and the products and processes are mature and production-ready, the nature of the relationships tends to change towards a transactional basis, which is exemplified in a supplier–customer relationship.

The selected case studies which will be discussed in this section aim to provide insight into manufacturing digitalisation, collaborations, impact of I4.0 horizontal integration on automotive manufacturers and the appropriation of value in different relationships within the manufacturing value chain. The four case studies were selected to provide a background to demonstrate the typical manufacturing value chain relationship and serve as a foundation to aggregate the data collected through the interviews and contractual analysis.

These case studies were selected as they represent the most common relationships (collaboration and supply/customer relationships) and variations of projects within the automotive manufacturing industry in the UK which typically fall under two categories (product or process development). The first type of project is focused on product development either for cost reduction, performance enhancement or both. The second type of project is normally focused on process / manufacturing technology development where the aim is operational improvement targeted at cost reduction.

Through these case studies the researcher aims to uncover and demonstrate the current practices and strategies for value creation, protection and appropriation in the manufacturing supply chain by examining the relationships from product or manufacturing technology development, through to the manufacture and supply of the product in the context of I4.0.

With the above needs in mind, a set of case study selection criteria was created and deployed:

i- The involvement of multiple actors in the automotive manufacturing value chain
ii- The ability to demonstrate strategic and transactional relationships in projects for development of new products
iii- The ability to demonstrate strategic and transactional relationships in projects for development of new processes or manufacturing technologies
iv- Access to the data related to the businesses in the value chain. These included the interviews and the actual contractual agreements governing the relationships.

In order to demonstrate the most common manufacturing relationships which were targeted with the case studies, the following figure was created. It shows the four quadrants of product and manufacturing technology, as well as the position of each selected case study.

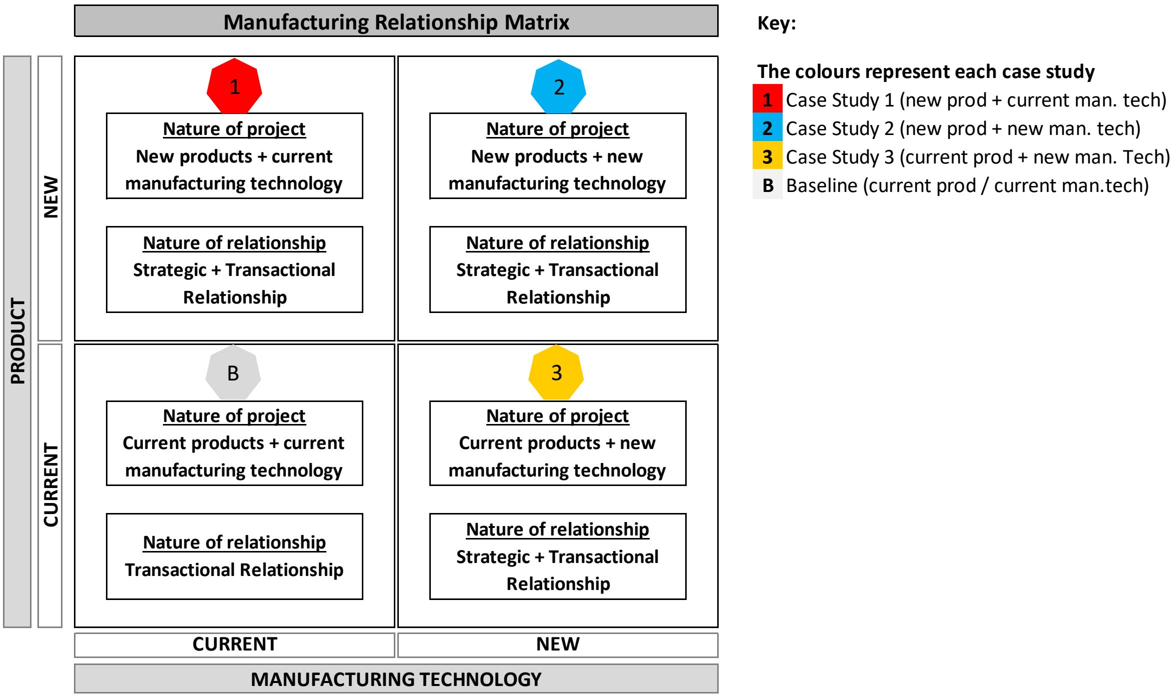

FIGURE 12 - MANUFACTURING RELATIONSHIP MATRIX

The figure highlights the position of each case study within the context of the research as described below. It is made of two axes representing the product and manufacturing technology dimensions. These two axes were used to create four quadrants demonstrating the combined case study scenarios.

The first axis on the left represents the product subject to the case study. This axis is subdivided into two sections, one representing current products in which I4.0 technologies were not utilised in its development and the other representing new products that utilised I4.0 in its development.

The second axis across the bottom represents the level of manufacturing technology subject to the case study. This axis is again subdivided into two sections representing current manufacturing technologies (pre-I4.0) and new manufacturing technologies where I4.0 is in operation.

Both axes have a simplified label representing a temporal indication of maturity: in essence, current and well-understood products and manufacturing technologies versus new and less-mature products and manufacturing technologies.

These two axes and four subdivisions form the four quadrants that capture the types of relationships evident in the automotive manufacturing supply chain collaborations, namely:

I - Bottom Left – Current product manufacturing with current manufacturing technologies. This quadrant represents projects where the nature of the relationships is transactional as there is no need for strategic relationships to develop new products or processes.

II - Top Left – New product development with current manufacturing technologies. This quadrant represents projects where the relationships evolve from a strategic collaboration to develop a new product, to a transactional relationship for the supply of this product to a customer (product R&D collaboration + supply contract).

III - Bottom Right – New manufacturing technology development with current products. This quadrant represents projects where the relationships also evolve from a strategic collaboration, which in this particular case is focused on developing new manufacturing technologies, but which nevertheless result in a transactional relationship for the supply of a product to a customer (process R&D collaboration + supply contract).

IV - Top Right – New product development with new manufacturing technology development. The projects in this quadrant are typically more complex and strategic as they involve a greater level of collaboration between the businesses in order to develop a new product and a new manufacturing technology which is interdependent as the production of the new product depends on the new manufacturing technology. This type of relationship also evolves from a strategic to a more transactional relationship; however, the collaborators have a higher level of dependency at the transactional stage of the relationship (product and process R&D collaboration + supply contract).

Furthermore, the figure also demonstrated the position of each of the selected case studies as summarised below and discussed in detail in Section 4.3 that follows.

I. Baseline Case study – This case study is focused on a product launch project, followed by a customer–supplier relationship in the manufacturing supply chain with the objective of producing a current product utilising current facilities and manufacturing technology.
II. Case Study 1 – Collaboration project, followed by a customer–supplier relationship in the manufacturing supply chain with the objective of developing and manufacturing a new product with the current manufacturing technology.
III. Case Study 2 – Collaboration project, followed by a customer–supplier relationship in the manufacturing supply chain with the objective of developing and manufacturing a new product utilising new technology.
IV. Case Study 3 – Collaboration project, followed by a customer–supplier relationship in the manufacturing supply chain with the objective of developing and manufacturing current products utilising new manufacturing technology.

4.3. Case Studies – Background

As mentioned in the previous section, the case studies were chosen to provide an account of the main types of relationship evident in the automotive manufacturing value chain. This section focuses on providing the background to the projects selected.

The following Figure 12 was created in order to summarise the nature or the relationships and projects covered by each of the case studies in the context of the Manufacturing Relationship Matrix presented in Figure 11. Furthermore, it also summarises the data collection sources used to characterise each of the relationships.

The case studies and the data collection methods will be explored during the next few sub-sections.

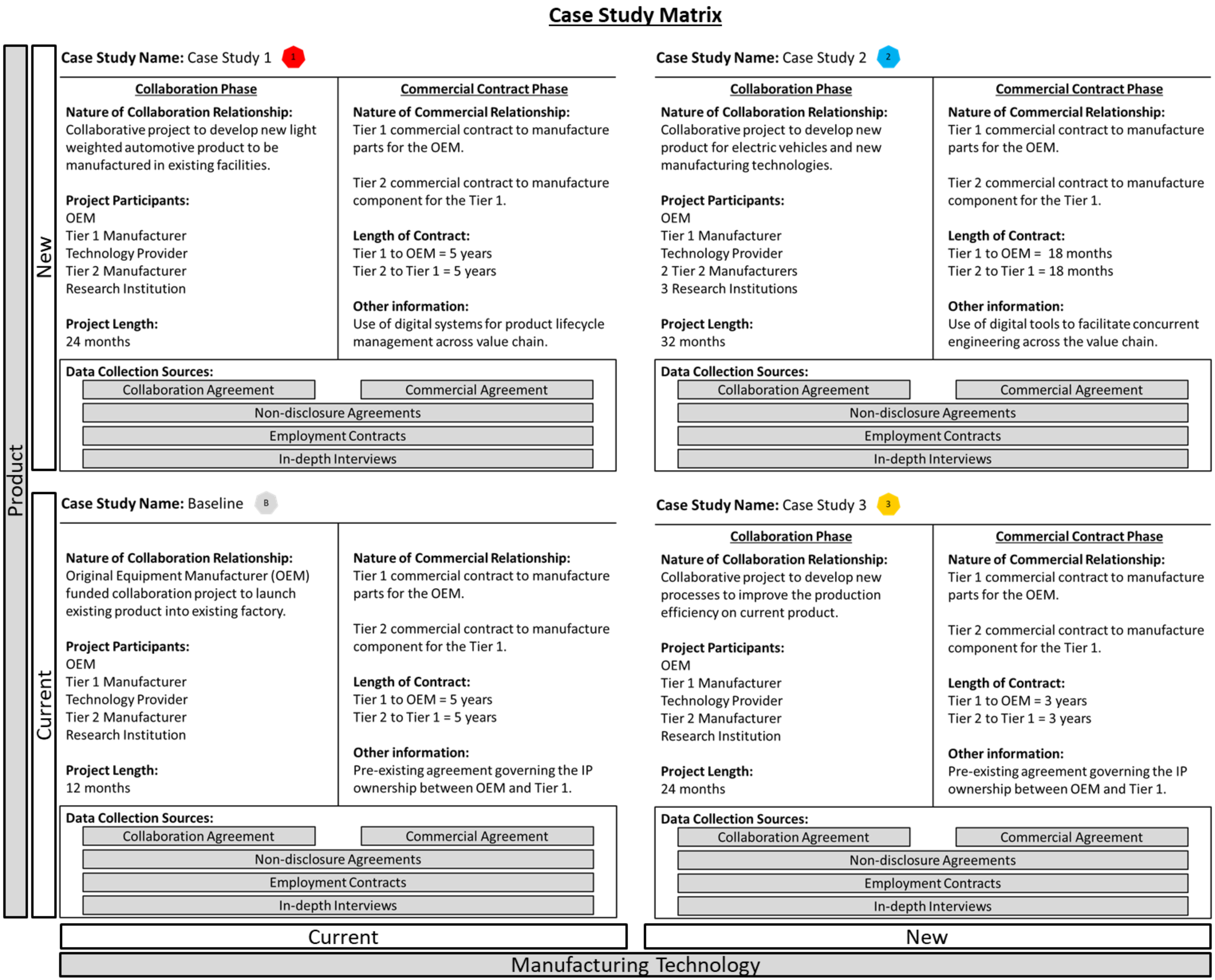

FIGURE 13 - CASE STUDY MATRIX

4.3.1 The Baseline Case Study

The baseline case study was designed to provide information regarding the current state of relationships in the automotive manufacturing value chain. This case study can be used to evaluate the impact of the change brought about by the implementation of I4.0 and to monitor and assess the progress of the manufacturing relationships before and after the activities covered by the other three case studies.

In the baseline case study the researcher has explored and collected data regarding a product launch project aimed at further developing a product and setting up the manufacturing operations for an automotive product already in production in another manufacturing plant. This project was part of a contract for the manufacture and supply of a product between a Tier 1 manufacturer and original equipment manufacturer in the automotive industry (vehicle manufacturer).

This project took place over a 12-month period and involved five parties from across the automotive manufacturing value chain, namely an original equipment manufacturing business (OEM), a vehicle manufacturer, a Tier 1 manufacturing business that supplies parts to the OEM (collaboration lead party), a technology provider who provides consultancy and engineering services in the automotive value chain, a research institution who provides applied research on operational excellence and a Tier 2 manufacturer that supplies components to the Tier 1 supplier.

The project was governed by a contractual agreement which established the roles and responsibilities of each of the parties as part of the launch project, as well as the rules regarding intellectual property. However, in this case there was a contractual relationship already in place between the OEM and the Tier 1 manufacturer which governed the ownership of intellectual property in relation to the product being manufactured.

Most importantly, this project is a baseline representation of the current technology in products and manufacturing processes with limited integration. The collaborating parties utilised tools and techniques that predate the I4.0 horizontal integration technologies and practices which are part of the other case studies. In this regard the individual businesses across the value chain operated in isolation with minimum data exchange. The Tier 1 manufacturer was already contracted to supply the product to the OEM for a period of five years, and the Tier 2 supplier was contracted for the supply of components to the Tier 1 supplier.

In this case study, the current practices and relationships in the automotive value chain in regard to manufacturing a product utilising current (pre-I4.0) manufacturing technology already in existence in a Tier 1 manufacturer plant were critically examined through the collection and analysis of data from multiple sources which will be discussed in more detail in Section 4.4.

4.3.2 Case Study 1

In Case Study 1, the research explores a relationship focused on a product development collaboration project, followed by a contract for the manufacture and supply of new product utilising current manufacturing technologies. In this case study the researcher has collected and analysed data regarding a collaboration project which took place over a 24-month period and involved five parties from across the automotive manufacturing value chain, namely an original equipment manufacturing business (OEM), a vehicle manufacturer, a Tier 1 manufacturing business which supplies parts to the OEM (collaboration lead party), a technology provider who provides consultancy and engineering services for product development in the automotive value chain, a Tier 2 manufacturer that supplies components to the Tier 1 supplier and a research institution that provides research support for new product development.

The aim of this project was to develop a new product capable of achieving higher functional performance compared to its predecessor. The main objective of this product improvement was to achieve lighter weight and cost in order to reduce the overall CO2 emissions for the vehicles utilising this part. The project was governed by a collaboration agreement which established the roles and responsibilities of each of the parties to the project, as well as the rules surrounding background and foreground intellectual property.

This project utilised the latest digital technologies for the product development, allowing the five collaboration parties to exchange product-related data and accelerate the product development cycle by running concurrent product design, design for manufacture and multiple product-related simulations. As such, this project provided a representative case study demonstrating the changes introduced by the use of I4.0 technologies for product development relationships in the automotive manufacturing value chain.

Upon the successful completion of this project, the Tier 1 manufacturer was awarded the contract for the supply of the product to the OEM for a period of five years. Subsequently, the Tier 2 supplier was awarded the contract for the supply of components to the Tier 1 supplier.

In this case study, the current practices in relation to a collaboration project to develop and manufacture a new product utilising current manufacturing technology available in an existing facility of a Tier 1 manufacturer in the automotive manufacturing supply chain were critically examined through the collection and analysis of data from multiple sources which will be discussed in Section 4.3.4.

4.3.3 Case Study 2

In Case Study 2 the researcher has explored and collected data regarding a collaboration project focused on product and new process development, followed by a contract for the manufacture and supply of new product utilising new manufacturing technologies. This project took place over a 32-month period and involved eight parties from across the automotive manufacturing value chain, namely OEM, Tier 1 manufacturing (lead party), a technology provider, two Tier 2 manufacturers and three research institutions.

The aim of this project was to develop a new product which forms part of the new generation of electric vehicles. As a consequence of the novelty of the product and the vehicle in which it is going to be utilised, this project also aimed to develop a novel manufacturing technology in order to enable the manufacturers involved to manage the high levels of product complexity surrounding manual process and high-precision joining techniques.

In the same way as Case Study 1, the Case Study 2 project was governed by a collaboration agreement which established the roles and responsibilities of each of the parties to the project, as well as the rules surrounding background and foreground intellectual property.

This project has utilised the latest digital technologies for the product and manufacturing technology development. This technology allowed the collaborating parties to exchange product and manufacturing-related data in order to virtualise the product and the manufacturing processes. As a result the value chain as a whole was able to accelerate the product and manufacturing development cycle by running concurrent product design, design for manufacture and multiple product and process simulations.

A number of digital models, also referred to as digital twins, were created to characterise and simulate the product and manufacturing performance with a high level of fidelity to the physical process. These models aggregated knowledge from multiple departments and disciplines across the collaborating parties. As an example, the operations team and the manufacturing engineering team provided real-life operational data to inform the simulation models utilised to refine the product design. As Case Study 1, this project provided a representative example of the changes introduced by the use of I4.0 technologies in the automotive manufacturing value chain in the context of product and manufacturing technology development relationships.

In a similar way to Case Study 1, upon the successful completion of this project, the Tier 1 manufacturer was awarded the contract for the supply of the product to the OEM for a period of 18 months. Subsequently, two of the Tier 2 suppliers were also awarded the contract for the supply of components to the Tier 1 supplier.

In this case study the researcher has explored the current practices in relation to a collaboration project to develop and manufacture a new product utilising new manufacturing technologies. These technologies were implemented into the facility of a Tier 1 manufacturer in the automotive manufacturing supply chain. Case Study 2 has provided an opportunity to critically examine the automotive manufacturing value chain relationships during the collaboration project, as well as during the contract for the supply of the product, via the collection and analysis of data from multiple sources which will be discussed in Section 4.3.4.

4.3.4 Case Study 3

In Case Study 3 the researcher has explored and collected data regarding a collaboration project which was aimed at a new process development, followed by a contract for the manufacture and supply of a current product utilising new manufacturing technologies. This project took place over a 24-month period and involved five parties from across the automotive manufacturing value chain, namely OEM, Tier 1 manufacturing, a technology provider (collaboration lead party), a Tier 2 manufacturer and a research institution.

The aim of this project was to develop a new manufacturing technology capable of achieving a higher level of productivity compared to previous manufacturing technology utilised to manufacture a product already under a contract of manufacture and supply between the OEM and the Tier 1 manufacturer.

In a similar way to the previous two case studies, the project was governed by a collaboration agreement which established the roles and responsibilities of each of the parties to the project, as well as the rules surrounding background and foreground intellectual property. However, in this case there was a contractual relationship already in place between the OEM and the Tier 1 manufacturer which governed the ownership of intellectual property in relation to the product being manufactured.

The collaboration project extensively used the latest digital technologies for manufacturing simulation at machine, production cell, production line and plant levels. These simulation models were used across the five collaborating parties to exchange data, accelerate the manufacturing process development and de-risk investment through digital validation. This project provided a representative example of the changes introduced by the use of I4.0 technologies in the automotive manufacturing value chain in the context of manufacturing technology development relationships.

Upon the successful completion of this project, the Tier 1 manufacturer was awarded an extension to the contract for the supply of the product to the OEM for a period of three years. The Tier 1 manufacturer was also awarded a contract to supply the same product to another continent for the extension period of three years. Subsequently, the Tier 2 supplier was awarded the contract for the supply of components to the Tier 1 supplier.

In this case study, the current practices in relation to a collaboration project to develop and manufacture a current product utilising new manufacturing technology implemented in an existing facility of a Tier 1 manufacturer in the automotive manufacturing supply chain were critically examined through the collection and analysis of data from multiple sources which will be discussed in Section 4.3.5.

4.3.5 The Case Study Data

The researcher collected data demonstrating the current relationships and practices in relation to the automotive manufacturing value chain and how these relationships are being affected by digitalisation. These case studies each explored multiple relationships with varying degrees of I4.0 technology deployment to develop and manufacture a product by a Tier 1 supplier to an OEM.

As mentioned in Chapter 3 regarding the research methodology, this study collected multiple sources of data which were combined into each case study. The data was collected through the following sources:

1 - The contractual analysis, which included the:

I - Collaboration Agreement

II - Supply Contract

III - NDA and Sample Employment Contract for the Tier 1 manufacturer employees

2 - The Interview data which included key informant Interviews and in-depth interviews included:

I - Interviewees representing each of the parties subject to each of the case studies

II - Interviewees representing multiple administrative departments from each of the parties subject to each of the case studies including sales, commercial and legal departments

III – Interviewees representing the engineering and research and development departments for each of the parties taking part in the case studies

IV - Interviewees representing operations management

V - Interviewees representing senior management and directors at each of the businesses participating in the case studies.

The data collected via the interviews was utilised in combination with the contract analysis in order to understand the impact of I4.0 in the context of each specific scenario. In addition, all of the interview data from across the case studies was utilised in an effort to identify common themes across the case studies and to shed light on the impact of I4.0 in the wider context of the horizontally integrated value chains. The results of this analysis will be presented in Chapter 5.

Having explored the case study selection and the background to each of the case studies to form part of this research, attention will now turn to the data collection methods deployed to gather data on the selected case studies.

4.4. Case study data collection

This section will describe one of the key data collection methods utilised in each of the case studies, i.e. the interviews. Such a method can be described as individuals directing their efforts for the purpose of improving the understanding and gaining an insight into the experiences, perspectives, concerns, beliefs, thinking and acting of the interviewee (Schostak 2006).

The literature in this area also points out the importance of interview aspects such as sampling in ensuring the reliability of the interviews as well as appropriate representation of the relevant population in order to inform the selected case studies. Furthermore, interviewee co-operation (willingness to discuss openly and honestly the topics of the interview) has also been highlighted as a crucial aspect of interviews which can be a very challenging area for researchers in terms of reaching a representative population.

As such, it was important for the researcher to carefully select the interviewee pool and work on the interview protocol in order to ensure that there was an opportunity to build rapport between the interviewee and the researcher to achieve an appropriate level of co-operation. Building a connection with the interviewees through the research protocol and the face-to-face interviews has a direct impact on the quality of the data (Groves 2004).

In the context of this study, interview methods were used to acquire information from employees of the selected businesses regarding the impact of I4.0 on their own organisations, particularly with regards to the changes in how businesses collaborate, as well as the role played by intellectual property in such relationships.

The interviews were split into two phases. The first utilised key informant interviews in order to collect first-hand accounts on the subject of the research by interviewing 10 key informants with relevant knowledge and experience. The number of interviewees was based on the need to include interviewees from of each of the businesses participating in each of the case studies and also cross-functional representation from each of the businesses in order to capture the multiple perspectives of interviewees involved in the particular relationships found in the manufacturing supply chain.

In the second phase, in-depth interviews were conducted with 21 interviewees from 10 different businesses, ranging from small to large, but all part of the manufacturing value chain. The interviews followed a semi-structured approach where a set of questions was prepared; however, these questions were open allowing the interviewees to introduce new ideas during the interview.

4.4.1 Recruiting Participants

In order to add to the research reliability, as well as to ensure that the research question was answered, it was important to capture a comprehensive cross-section of businesses involved in the case studies across the automotive manufacturing value chain, whilst allowing for constraints and practicalities.

The criterion for selection applied was whether the business was, firstly, part of the automotive manufacturing value chain; secondly, whether the business was engaged in I4.0 projects; and finally, the business had to be engaged in at least one of the collaborations or relationships selected for the case studies mentioned in Section 4.3 of this chapter.

As mentioned in Chapter 3, the researcher benefits from being an 'insider' and, as such, his current network was utilised to derive the initial list of businesses to which the selection criteria were applied. Once the businesses were identified, the researcher utilised his contacts within those organisations in order to identify a pool of suitable participants with knowledge of the subject areas of the research study, and working within the one of the selected case studies identified in section 4.2.

The table below demonstrates the initial interviewee pool for key informant interviews. It lists the basic information regarding the participant value chain position (left column) and their role in the organisation (right column).

Interview	Position in the value chain	Position in the organisation
1	Tier 1 Automotive Manufacturer	Engineering Director
2	Tier 1 Automotive Manufacturer	Commercial Director
3	Tier 2 Automotive Manufacturer	Operations Director
4	Original Equipment Manufacturer	Engineering Manager
5	Engineering Consultancy	Operations Director
6	University Enterprise	Research Manager
7	Legal Services Provider	Director
8	Legal Services Provider	Senior Associate
9	Original Equipment Manufacturer	Legal Associate
10	Tier 1 Automotive Manufacturer	Senior Engineer

TABLE 4 - KEY INFORMANT INTERVIEW TABLE

4.4.2 Sampling Frame

In order to ensure the quality of the data collected, the researcher developed and applied a sampling frame aimed at capturing responses from individuals with relevant experience and knowledge to provide representative data for their organisation in the context of each of the case studies.

Given the novelty of the research subject, the task of identifying and agreeing the interviews with the interviewees was challenging. Such challenge was not in relation to the ability to reach a cross-section of interviewees from the businesses involved in the case studies, but rather the ability to reach individuals with knowledge of the subject matter. This fact is, in itself, a relevant finding for the research as it demonstrates that – in practice – there is a general lack of understanding by the key actors involved in the process of implementation of I4.0 that emphasises the importance of this research in improving the prospects of its practical impact.

In order to identify further individuals with relevant knowledge within the selected businesses, the interview structure utilised elements of ‘snowball sampling’, as participants were asked for recommendations on further interviewees within their organisations. According to Atkinson and Flint (2001, p. 1), snowball sampling is at odds with traditional sampling criteria due to a lack of randomness. However, Atkinson and Flint also pointed out that it leads to a better chance of identifying ‘experts’ within an organisation.

In true snowball sampling, interviewees are encouraged to suggest further interviewees with relevant knowledge in the case study, and every lead would be followed. However, in this research, only leads that were deemed relevant, based on the interviewee selection criteria and potential importance to the research, were followed.

The following table was created to demonstrate the results from the sampling technique applied throughout the 10 key informant interviews. The table shows 30 interviewees from across the businesses participating in the case studies.

Interview	Organisation size	Position in the value chain	Position in the organisation
1	Large	Tier 1 Automotive Manufacturer	Managing Director
2	Large	Tier 1 Automotive Manufacturer	Sales Director
3	Large	Tier 1 Automotive Manufacturer	Engineering Director
4	Large	Tier 1 Automotive Manufacturer	Commercial Director
5	Large	Tier 1 Automotive Manufacturer	Strategy Director
6	Large	Tier 1 Automotive Manufacturer	Engineering Manager
7	Large	Tier 1 Automotive Manufacturer	Operations Director
8	Large	Tier 1 Automotive Manufacturer	Finance Director
9	Large	Tier 2 Automotive Manufacturer	Operations Director
10	Large	Tier 2 Automotive Manufacturer	Senior Manager
11	Large	Engineering Consultancy	Operations Director
12	Large	Engineering Consultancy	Engineering Director
13	Large	Original Equipment Manufacturer	R&D Director
14	Large	Original Equipment Manufacturer	R&D Director
15	Large	University Enterprise	Director
16	Large	University Enterprise	IP Manager
17	Large	Original Equipment Manufacturer	IP Manager
18	Large	Legal Services	Director
19	Large	Legal Services	Associate
20	Large	Government Organisation	Research Manager
21	Large	Research Organisation	Associate
22	Medium	Tier 2 Automotive Manufacturer	Senior Engineer
23	Medium	Tier 2 Automotive Manufacturer	Senior Buyer
24	Medium	Legal Services	Senior Manager
25	Medium	Legal Services	Senior Manager
26	Large	Original Equipment Manufacturer	Senior Engineer
27	Large	Original Equipment Manufacturer	Senior Manager
28	Large	Original Equipment Manufacturer	Project Manager
29	Medium	Technology Centre	Senior IT Manager
30	Medium	Technology Centre	Senior Buyer

TABLE 5 - DATA COLLECTION ENGAGEMENT MATRIX

The engagement matrix shows from left to right, the interview number, the size of the organisation, the value chain position of the organisation and the individual role within the organisation.

Following the high-level description of the interview data collection method as KII and IDI, as well as the approach utilised to recruit participants, attention will now turn to the specific processes used to collect the primary data through KIIs and IDIs.

4.4.3 Key Informant Interviews (KII)

This section is aimed at describing the KIIs, and the process utilised to collect and process the interview data. The following table was created to summarise the key informant method deployed.

Data Collection Method	Key Informant Interviews
Definition	Method of interview focused on people with first-hand knowledge and experience in the object of research
Scope	To interview and gain foundational knowledge from subject area experts in their respective fields which include Industry 4.0 technologies, business models and intellectual property strategies in manufacturing
Objective	To validate the research assumptions, narrow the objects of the research, contribute to foundational knowledge and identify participants for in-depth interviews
Deliverable	Contribution to research framing, literature review, data collection activities and the theory formation

TABLE 6 - KEY INFORMANT INTERVIEW METHOD SUMMARY

The key informant interviews were scheduled during the months of July and August 2017, at each participant's office premises, and took between 35 and 45 minutes each. The KIIs were designed to be quite informal and open in order to avoid restricting the participants. As such, there were no specific questions for the KIs, but rather a set of key topics for discussion, namely I – Provide a brief overview of the research; II – Discuss the participant's views regarding the research validity (which will be explored in more detail below); III – Collect key information regarding the participant's experiences and views on the topics of research; and IV – Discuss future direction ideas.

The following sections will provide a summary of the areas covered by each topic as part of the KII protocol.

I – Provide a brief overview of the research

In this part of the interview, each participant was presented with 10 slides containing:

1 - Research Title and Questions

2 - Research Propositions

3 - Research Framework

4 - Topic Summary – Industry 4.0

5 - Topic Summary – Business Model

6 - Topic Summary – Intellectual Property

7 - Research Objectives

8 - Research Plan

9 - Data Collection Plan

10 - Any Questions for the KI

After the presentation of the above slides, the KIs were encouraged to ask any questions regarding the content and to feedback on their initial thoughts.

II – Discuss the Participant's views regarding the research validity

Following the research overview, the KIs were asked to provide feedback as to the research enquiry validity.

The following list contains the three most frequent questions:

What are your views regarding the research question?

Do you agree or disagree with the relevance of the research propositions?

Do you believe that the research has the potential to advance theoretical and practical knowledge?

III – Collect key information regarding the participant's experiences and views on the topics of research

Following on from the research validity questions, the participant was asked to provide his/her experiences and views regarding the key three areas (I4.0, BMs and IPS). The typical questions included:

What are your views and experiences regarding each of these areas?

Do you or your business see this area as a potential opportunity or challenge?

Are you currently working to address any of these opportunities or challenges?

IV – Discuss future direction ideas

Finally, the participants were encouraged to discuss any particular areas of interest regarding the research or any particular suggestions for topics or issues relating to the research areas, as well as potential participants for the in-depth interviews.

The researcher has allowed the participants to expand the discussion and provide their personal views and opinion regarding the I4.0 and any personal perspectives on challenges and opportunities for the interviewees themselves, rather them their businesses.

Each set of interview notes was then transcribed into a KII data matrix and summarised into the key points for each of the topics discussed as shown in the following table.

KII protocol	Interview notes
1 - Provide a research overview 2 - Discuss research validity 3 - Collect information on perceptions and experiences 4 - Discuss future direction ideas	1- The research overview was presented and understood. 2- The topic is very interesting and relevant to our business, but we are nowhere near this level of integration discussed in your research overview. I would be very interested in the findings and recommendations from it. 3- Industry 4.0 is not very well understood at the moment, and we will take time to get the grips with it. In terms of IP, at the moment we have none, and it is not really given much importance in our business. I would like to see what the potential benefits and risks associated with not having IP are, but at the moment it makes no difference to us. 4- It would be interesting to understand what IP could do for our manufacturing business today and how that would change in the future. Also, any roadmaps to Industry 4.0 implementation would be valuable to us.
1 - Provide a research overview 2 - Discuss research validity 3 - Collect information on perceptions and experiences 4 - Discuss future direction ideas	1- The research overview was presented. 2- I like how you are approaching these issues. The research structure is very interesting, and I've never looked at Industry 4.0 from this perspective. To be honest, I am not very close to intellectual property, but the supply chain transformation makes sense and may have an impact on our know-how. 3- Industry 4.0 is not in our strategy plans yet, but we are already working with many digital technologies. We have used robots, sensors, actuators, etc. for many years. At Toyota we used most of these back in the 80s. I am still to see it coming over in the horizon, but that may be few years away for us. Maybe it makes more business sense to larger manufacturers and OEMs. 4- The project makes sense to me, but I think that we may struggle to get that level of business transformation. It would be very useful if you could provide some examples of Industry 4.0 implemented in manufacturing businesses in order for us to see how it looks like rather than just talk about it in abstract.

TABLE 7 - KII SAMPLE DATA TRANSCRIPTION

The above table shows the meeting protocol on the left column and the summary of the transcribed notes on the right column.

The key themes emanating from the KII interview data transcription summary notes were then combined with the researcher's comments, and a number of themes were derived in order to support the formulation of the in-depth interviews as shown in the following table which shows the summarised notes from the KII on the left, followed by the researcher comments in the centre and the key themes on the right.

The key informant interviews provided a valuable source of data and a number of key insights in the form of key themes that helped the researcher to shape the in-depth interview protocols and also identify interviewees.

Interview notes	Researcher comments	Key themes to
1- The research overview was presented. 2- I like how you are approaching these issues. The research structure is very interesting, and I've never looked at Industry 4.0 from this perspective. To be honest, I am not very close to intellectual property, but the supply chain transformation makes sense and may have an impact on our know-how. 3- Industry 4.0 is not in our strategy plans yet, but we are already working with many digital technologies. We have used robots, sensors, actuators etc. from many years. At Toyota we used most of these back in the 80s. I am still to see it coming over in the horizon, but that may be few years away for us. Maybe it makes more business sense to larger manufacturers and OEMs. 4- The project makes sense to me, but I think that we may struggle to get that level of business transformation. It would be very useful if you could provide some examples of Industry 4.0 implemented in manufacturing businesses in order for us to see how it looks like rather than just talk about it in abstract.	The KII found the research to be innovative. "Industry 4.0 is not part of our strategy yet". (Very interesting remark given that the business is involved in many I4.0 projects.) "We already use most of the technologies. Toyota used some since the 80s". (Another surprising remark! No distinction between standalone use of technology and I4.0.) The KII is not close to/aware of IP. (Clearly no link between I4.0 and risks to IP.)	Lack of I4.0 understanding and evidence of silos in I4.0 projects within the business. Confusion between new and old manufacturing technologies such as robotics/cobots and I4.0. Lack of IP awareness.
1- Research overview was presented and understood. 2- I find that the research question is absolutely valid as I find it very interesting and I would not be able to answer the IP-related aspects of it, let alone the whole question. 3- As an IP attorney I obviously experience Industry 4.0 through our clients. I can say that we have seen very little in terms of patents or even any IP discussion on this front. What we have experienced is a lot more collaboration between business and the use of IOT and cloud computing, which changes the way people protect confidential information and other intangible assets for that matter. I can also say that most of our customers have an idea about IP and potentially some will even have an IP strategy; however, I have not seen anyone with a clear strategy as to which or how much information they choose to share in their collaborations. It appears that this process is very organic and will be developed in a different way in each collaboration. Maybe we should offer some education and advice to our customers on this front and most issues can be addressed upfront if they ask the right questions. 4- You should have a look at the work Microsoft and Siemens are doing on the IOT platforms and how they are addressing some of the issues regarding IP security and cybersecurity. I think that your research is very important and could be key in helping us understanding the challenges. I would be interested in discussing your findings and how we can better help our clients to deal with future challenges.	The KI has shown interest in the research and an element of surprise from the connection between I4.0 and IP. ""I can say that we have seen very little in terms of patents or even any IP discussion on this front...". (Very interesting point, over 100 clients in the mfg. value chain and little mention of I4.0.) "I have not seen anyone with a clear strategy as to which or how much information to share...". (Key point about disconnect between IP strategy and data sharing.) (Must account for questions regarding collaborations in the in-depth interviews as business may not distinguish between I4.0 and collaboration projects.) Look at Microsoft and Siemens IOT Platforms. (KI interested in results and impact on his customers.)	No evidence of I4.0 within the automotive manufacturing value chain. Disconnect between IP strategy and data-sharing strategy. Limited view of IP as only registered IP. I4.0 as another type of collaboration!?

TABLE 8 - SAMPLE DATA SUMMARY WITH COMMENTS AND THEMES

The KIIs were invaluable as a first experience in data collection that exposed the researcher to some of the challenges regarding semi-structured interviews and the amount of data generated in the process. Also, the opportunity to refine the approach and the data collection practicalities, such as using a recording device and automatic transcription, were paramount to enable the researcher to conduct the in-depth interview as will be discussed in the next section, 4.4.4.

4.4.4 In-Depth Interviews (IDI)

This section describes the IDIs, and the process utilised to collect and process the in-depth interview data for this study. The following table was created to summarise the in-depth interview method as applied by the researcher.

Data collection method	In-depth interview
Definition	The method of interview study used was semi-structured allowing freedom for both the interviewer and the interviewee to explore additional points and change direction if necessary.
Scope	To utilise semi-structured interviews with individuals subject to the object of the research in order evaluate the theoretical findings and contribute to framework development. It is expected to include academics, business leaders and other practitioners.
Objective	To validate the theory assumptions, contribute to framework development and validation.
Deliverable	Contribution case studies, framework development and validation.

TABLE 9 - IN-DEPTH INTERVIEWS SUMMARY

In order to ensure that each in-depth interview was consistent, an interview protocol has been created by the researcher. The protocol was informed by the literature review and by the KIIs; it included a list of questions that ranged from an ice-breaker question to the capture of basic interviewee information, followed by a set of questions for each of the key areas of research (I4.0, BM and IP strategy).

The following Table 10 below was created to demonstrate the in-depth interview questions. It shows, from left to right, the question number, the question theme and the interview question.

#	Question theme	Interview question
1	Rapport building	Interviewee details and background
2	Rapport building	Company details and background
3	Industry 4.0	Are you currently involved in any Industry 4.0 related activity? If so, what is the scope of the activity?
4	Industry 4.0	How would you define/describe Industry 4.0 and the vertical and horizontal integration?
5	Industry 4.0	Overall, do you believe that Industry 4.0 will be beneficial to your business? If so/not, why?
6	Industry 4.0	How would you describe the status of Industry 4.0 implementation in your business?
7	Industry 4.0	What are the expectations regarding long-term threats, opportunities, risks and benefits in relation to Industry 4.0?
8	Industry 4.0	What are the key difficulties/risks if any, in relation to Industry 4.0 implementation?
9	Industry 4.0	In your view, how adaptable to change is your business? How strong is your change management process?
10	Business models	Would you be able to articulate what your current business model is (nine basic building blocks)?
11	Business models	Which areas of your business model will be impacted by Industry 4.0?
12	Business models	What are the challenges, risks and opportunities in relation to the areas impacted by the Industry 4.0 implementation?
13	Business models	Do you foresee the need for adapting your current business model? Why? And how are you planning to do so?
14	Value chain relationships	Are you currently involved in industrial collaborations? If so, with what partners (suppliers, customers, consultants, universities, others)?
15	Value chain relationships	At what stage of the product/service life cycle do you normally collaborate?
16	Value chain relationships	How much R&D and operational data do you currently exchange with your partners?
17	Value chain relationships	How critical to the development of products and services are your current collaborations?
18	Value chain relationships	Overall, do you believe that collaborations are positive? If so, why/why not?
19	Value chain relationships	In your view, what would be the impact of full vertical and horizontal integration of your business to your suppliers and customers?
20	Value chain relationships	Have you experienced loss of business/opportunity/value due to oversharing information with collaborators?
21	Intellectual property	In your view what is intellectual property? What is IP for you and your business?
22	Intellectual property	Does your business currently own or license any intellectual property?
23	Intellectual property	What in your view is an IP strategy?
24	Intellectual property	Does your business utilise an IP strategy? If so, what is the organisational scope of such strategy?
25	Intellectual property	In your view, how important is IP for your current business model?
26	Intellectual property	In regard to your past collaborations, have you experienced any loss or gain of IP?
27	Intellectual property	In your view, how important is IP for the future of your company in the context of horizontal integration?

TABLE 10 - IN-DEPTH INTERVIEW PROTOCOL

Furthermore, the researcher has also created Table 11 demonstrating the relationships between the interview questions and the research questions. The first columns on the left shows the question number and the four columns on the right demonstrate the relationship of each interview question with the main research question and sub questions.

The colours used in the intersection between the interview question and the research question show the correlation intensity. White was used where there was no obvious direct correlation, yellow was used for some correlation and green was used were there was a strong correlation between the interview question and the research question.

#	What is Industry 4.0 and horizontal integration in the context of Industry 4.0?	How is horizontal integration likely to impact current manufacturing business models?	How is horizontal integration likely to impact manufacturing intellectual property strategies?	How can the current IP strategies be adapted in order to address the risks and opportunities regarding value appropriation in the manufacturing value chain?
1				
2				
3	XXX			
4	XXX			XXX
5	XXX		XXX	
6	XXX		XXX	
7	XXX		XXX	
8	XXX		XXX	
9	XXX	XXX	XXX	
10		XXX	XXX	XXX
11		XXX	XXX	XXX
12		XXX		XXX
13		XXX		XXX
14		XXX		
15		XXX		
16		XXX		
17		XXX		
18		XXX		
19		XXX		
20		XXX		
21			XXX	XXX
22			XXX	XXX
23			XXX	XXX
24			XXX	XXX
25			XXX	XXX
26			XXX	
27			XXX	

TABLE 11 - INTERVIEW QUESTIONS AND RESEARCH QUESTIONS MATRIX

The actual IDI interviews were conducted at the participant's premises and took between 60 and 90 minutes each. The following is a generic description of the process deployed in order to record and transcribe each of the interviews.

Step 1 – At the beginning of each IDI the researcher presented the participant with the FBL Participant Information Leaflet and the FBL Informed Consent Form (provided in Appendices 1 and 2).

Step 2 – Upon agreement to participate and completion of the forms, the recording device was configured and turned on.

Step 3 – The interview questions as per the above protocol were posed to the participant and, when appropriate, followed by further questions.

Step 4 – Upon completion, each of the interview recordings, which were made utilising the Smart Recorder Application for iPhone, were emailed from the device to the researcher's email account.

Step 5 – The interview recordings were converted from an mp3 file into and mp4 file.

Step 6 – The mp4 interview files were loaded into the video editing software, which automatically generated closed captions for the interview. These closed caption files were in turn saved into a text file, to create a rudimentary transcription.

Step 7 – The text files were individually copied and pasted into an Excel spreadsheet where blank rows and numbers were deleted.

Step 8 – The rudimentary transcription was then copied into a Word document template created for each interview. During this final step of the process, the researcher would validate each individual question and answer for accuracy, as the automatic closed caption process is estimated to be only 60 to 70% cent accurate.

Step 9 – The validated transcript files were uploaded into NVivo in preparation for coding during the data analysis stage of the research.

4.4.5 Contractual Data Collection

Throughout the data collection stage of the research, contractual agreements related to the case studies were collected, analysed and cross-checked in order to improve the reliability of the findings made in this study. The following section explores how the contractual data collection was executed.

Contractual data collection in the context of the case studies for this research was used in order to provide a rich source of objective data demonstrating the actual practices regarding the relationships in the automotive manufacturing value chain. The particular contracts analysed during this study were sourced through the interview participants and their businesses, as a form of data validation and triangulation of the interview data and the findings from the literature review.

The contracts covered the collaboration agreements for product or technology development, as well as the employment contracts and the contracts for the provision of goods or services in relation to the case studies to be discussed in section 4.2.

The table below shows a list of all contracts utilised to source data for the purposes of this research.

#	Contract identifier	Document description
1	Lambert Model - Collaboration Agreement	Model agreement for research collaborations
2	Lambert Model - Consortium Agreement	Model agreement for consortium collaboration
3	I - Consortium Collaboration Agreement	Actual example of consortium collaboration agreement for current product, new technology
4	II - Consortium Collaboration Agreement	Actual example of consortium collaboration agreement for new product, current technology
5	III - Consortium Collaboration Agreement	Actual example of consortium collaboration agreement for new product and new technology
6	Tier I - Standard NDA	Standard Non-Disclosure Agreement used by Tier 1 automotive
7	Tier I - Employment Contract	Standard Employment Contract used by Tier 1 automotive
8	Tier I - Contractor Contract	Standard External Contractor Agreement used by Tier 1 automotive
9	OEM A - Standard Supplier Contract	Example of standard OEM terms and conditions for the supply of parts by Tier 1 automotive
10	OEM B - Standard Supplier Contract	Example of standard OEM terms and conditions for the supply of parts by Tier 1 automotive
11	OEM C - Standard Supplier Contract	Example of standard OEM terms and conditions for the supply of parts by Tier 1 automotive

TABLE 12 - CONTRACTUAL DATA COLLECTION

In column on the left, labelled 'Contract identifier', the researcher has listed the type of contract that was provided by the parties to the three case studies. In the column on the right, the researcher has provided a brief description of the specific contract.

The following paragraphs describe how the data was extracted from each of the documents and summarised into a single data set ready for analysis using the following steps:

1. The contract was read for an initial overview.
2. The contract was read for a second time with the specific objective of highlighting the clauses related to intellectual property. These included clauses impacting any rights or obligations regarding intellectual assets in the form of background or existing IP owned by the parties to the agreement as well as foreground or resulting IP.
3. The contract was read for the third time, and the highlighted clauses were validated for relevance (does the clause relate to the subject of research, e.g. IP, confidentiality and data sharing?) and copied into an Excel table that categorised each type of clause.
4. The table was in turn summarised and compared in a matrix (the clauses in each contract were compared for consistency, and the clauses from different contracts were compared to identify the stances in each contract type (collaboration agreement vs supply of goods and services).
5. Conclusions and comments were made for each of the clauses and contracts.
6. The matrix with all the data was loaded into the data analysis tool.

The contractual data was critical to the study, in that it provided the researcher with an objective view of the relationships forming part of each of the case studies. As will be discussed in Chapter 5 as part of the data analysis, there were multiple instances where the contractual agreements conflicted with the interviewees' description of their businesses' stance in regard to collaborations in the value chain.

The provision of this objective view of the automotive manufacturing value chain meant that the data collected through the contracts has proven paramount to the appropriability analysis framework developed as part of this research.

After exploring the data collection processes, attention will now turn to a summary of the data collected, how it was aggregated and some preliminary interpretations.

4.5. Data Collection Summary

The data collected was analysed using a Computer Assisted Qualitative Data Analysis tool. The interviews recorded and transcribed were then analysed using the computer system in order to identify the key factors and themes that present a level of similarity across the various data collection methods. This textual analysis of interview transcripts was completed using the NVivo software. This approach provides various benefits if compared to manual analysis, as NVivo offers a wide spectrum of methods and tools for the analysis of the data collected.

This research utilised the program to categorise the direct quotes into an initial text segmentation, to create the first-order and second-order codes, as well as to aggregate the data into key themes and explore the data in more detail within each theme.

A system of coding methods was used in order to interpret and give meaning to the data collected. A code in this context is a word, phase or sentence that represents an aspect of the data and captures the essence or the key features of the data (Saldaña 2013).

According to the literature on qualitative research, the analysis of qualitative data is a process of systematic interpretation focused on identifying meaningful patterns, themes and concepts which will support the research enquiry (Gray 2009; Silverman 2010; Berg and Lune 2012).

Gray (2009) argues that qualitative data analysis is prone to researcher subjectivity. It is also argued that such analysis lacks a robust set of rules (Saldaña 2013) when compared to the rigour deployed in quantitative data analysis. Qualitative data is rich and able to support the creation of themes, concepts, frameworks and theories derived from the data collected in regard to a development such as I4.0 without being confined to statistical analysis (Neuman 2003).

The following Figure 13 was created to show the data collected and aggregated.

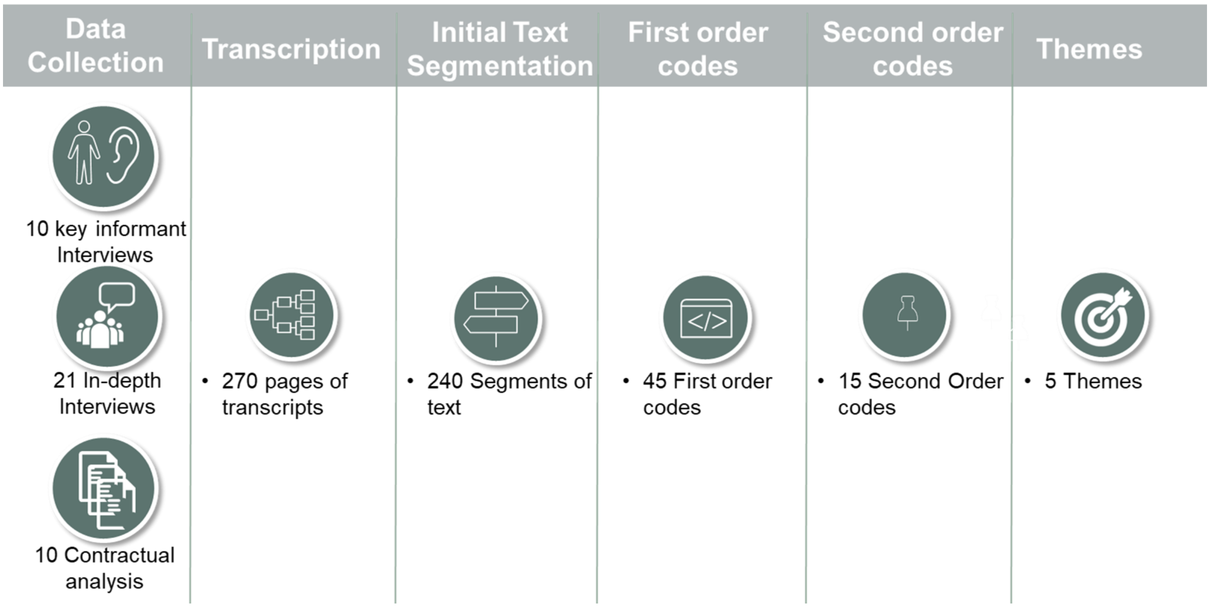

FIGURE 14 - DATA COLLECTION SUMMARY

From left to right, the figure demonstrates a summary of the data collection containing the following five steps:

I- In the first step the raw data resulting from the interviews containing over 2,000 minutes of audio interviews was transcribed and combined with the contractual data into 270 pages of transcripts, which were imported into NVivo.

II- In the second step, the transcripts were analysed and coded into 240 relevant text segments highlighted directly from the transcripts.

III- In the third step, the text segments were clustered to provide a set of 45 first-order codes based on similar topics which emanated from the transcripts.

IV- In the fourth step, the 45 first-order codes were grouped into 15 second-order codes, which provided a brief statement encompassing similar codes.

V- Finally, in the fifth step, the second-order codes were utilised to generate five core themes emanating from the combined data collected.

These themes, which will be discussed in detail in Chapter 5, were used in the context of the case studies analysis and to answer the research questions.

4.6. Chapter 4 Conclusion

This chapter set out to provide a description of the data collected through the interviews, contractual analysis and the case studies. It explored the case study selection in section 4.2, the case studies background in 4.3, the actual data collection via multiple methods in 4.4 and finally, the chapter offered a summary of the data collected in section 4.5. Having explored the data collection for the research, attention will now turn to the data analysis chapter where the data collected will be analysed in detail in the context of the three case studies described above.

5. Chapter 5 – Data Analysis

5.1. Introduction

In Chapter 5 the researcher will present the data analysis by first exploring the themes emerging directly from the coding process and second, by showing the results of the analysis utilising a new appropriability regime framework which demonstrate the impact of the implementation of I4.0 on each of the case studies.

The data analysis for this study focused on inductively searching for patterns in data, rather than applying a pre-existing framework and searching for the framework's constructs in the data (Martin and Turner 1986; Easterby-Smith, Thorpe and Jackson 2008; Locke 2001; Glaser & Strauss 1967). Easterby-Smith, Thorpe and Jackson (2015) argue that coding is a particularly relevant analytical approach for this type of research because it enables the researcher to tackle empirical data in an open way.

Coding can be defined as the process of systematically analysing qualitative data by labelling it (Malterud 2012). Coding can be done either by designing a number of codes in advance and then attributing these to the text (i.e. a priori codes), or progressively designing codes based on the data content.

Coding is often done in two steps, where a number of first-level codes are attributed to the text and then organised and clustered into sets of second-level codes covering, for example, overarching themes of the first-level codes (Saldaña 2015). For both these levels of code, multiple approaches can be used, e.g. letting codes describe the theme of a quote, summarising the content of a quote, and so on. In this analysis, the 21 in-depth interviews collected were transcribed and coded into 45 first-order codes (in NVivo). These codes were directly linked to excerpts from the transcribed interviews. As such, no a priori codes were imposed on the interview data; instead, the codes emerged by labelling the transcribed data during the analysis process.

The analysis relied on what is described by Hsieh and Shannon (2005) as “conventional coding”, as the emerging codes were reused multiple times and linked to 238 quotes from the 21 interviews. The approach utilised by the researcher was to link the first order codes and maintain a close resemblance to the original text excerpts. This approach is particularly relevant in studies on phenomena such as the subject of this research, which is novel and had limited exposure to prior research.

The next step in the analysis revolved around clustering the list of first-order codes around similar topics. This clustering process was primarily done through analysis between the similar first-order codes. In essence, distinct clusters were created, aggregating text segments from the interviews and the contractual analysis. These clusters were then compared for further clustering. This process resulted in 15 second-order codes derived from the first-level codes.

Finally, the 15 second-order codes were organised into higher-level themes. These themes were derived from a parallel analysis of the literature review and the theory discussed in Chapter 2, in order to find relevant overarching themes that could be used to correlate the data collected from multiple sources under the three case studies as discussed in Chapter 4.

In this manner, the data analysis of the first and second order codes were in their nature inductive, as no initial framework was imposed onto the data. This was deemed important due to the purpose of the study. Forcing data into a pre-defined framework would risk overlooking potentially novel findings. For the themes, however, theory and empirical data was compared in order to determine how the empirical findings were reflected in earlier literature, as well as to locate the data within the case studies. From this comparison, new theoretical insights emerged. As such, the themes can be said to have emerged in an inductive manner by moving back and forth between primary and secondary data as described by Dubois & Gadde (2002).

The following table was created by the researcher to show, from left to right, the first and second-order codes and the five themes, organised and coloured according to their relationship.

Data Collection Coded					
Code #	**First Order Codes**	**Code #**	**Second Order Codes - Reduced**	**Code #**	**Emerging Themes**
F1	The industry is demanding digitalised businesses	S1	There is an acceptance that businesses need to digitalise	T1	Industry 4.0 leads to shift in the nature of knowledge towards codification
F2	Demand for digital skills and digital natives				
F3	On-going Digitalisation programmes				
F4	Digitalisation of knowledge	S2	There is evidence of increased codification of knowledge and increase in collaborations		
F5	New digital tools for planning				
F6	New digital tools for execution				
F7	Awareness of importance of knowledge	S3	There is a recognition that manufacturing is moving towards a knowledge based economy		
F8	Increase in R&D activities				
F9	Moving into high-value manufacturing				
F10	Impact on operational Efficiency	S4	There is a general lack of clarity on the value of digitalisation for manufacturing	T2	Evidence of preparadigmatic phase in digital manufacturing
F11	Impact on customer relations				
F12	Potential business growth				
F13	Unsure of the short term benefits	S5	There is uncertainty regarding “risks and benefits” of digitalisation of manufacturing		
F14	Risk awareness is limited				
F15	Difficulties with the speed of change				
F16	Real life examples	S6	There are no real examples to demonstrate Horizontal Integration in manufacturing		
F17	Limited case studies				
F18	Examples of localised operational benefits				
F19	Increase in collaborations exchanging data	S7	There is evidence of increased knowledge transfer collaborations	T3	Evidence of recognition of a shift on tangible/intangible asset as source of competitive advantage
F20	Knowledge intensive collaboration				
F21	Increasingly targeted collaborations				
F22	No business model impact	S8	There is uncertainty as to how digitalisation will affect BMs for manufacturers, but there is recognition that intangible assets are increasingly		
F23	Digitalisation will change our business models				
F24	Intangible assets importance				
F25	Intangible assets for competitive advantage	S9	There is recognition that knowledge and intellectual property is key to competitive advantage		
F26	Intangible assets for differentiation				
F27	Intellectual Property importance				
F28	Registered Intellectual Property	S10	There is evidence that manufacturing businesses typically use a very narrow definition of IP	T4	Evidence of limited knowledge and application of protection mechanisms for value appropriation
F29	Intellectual Property for protection				
F30	Intellectual Property costs				
F31	No Intellectual Property Strategy	S11	There is evidence that manufacturing Businesses do not have an IP strategy to protect innovation		
F32	Intellectual Property Ownership				
F33	Intellectual Property in Innovation projects				
F34	Intellectual Property Law	S12	There is recognition that IP knowledge should be decentralised to all functions		
F35	Intellectual Property Education				
F36	Intellectual Property Management				
F37	Changes to value generation and distribution	S13	There is uncertainty as to how digitalisation will affect BMs for manufacturers	T5	Evidence of lack of awareness of change in the appropriability regimes
F38	Changes to value proposition				
F39	Supplier and Customer Relationships				
F40	Awareness of intangible asset benefits	S14	Manufacturing businesses typically use a very narrow definition of IP as a protection mechanism, but not as a source of revenue		
F41	Intellectual Property Revenue				
F42	Intellectual Property other benefits				
F43	No need for an Intellectual Property Strategy	S15	There is no evidence of manufactures adapting their IP strategies due to digitalisation		
F44	Follow the market pull				
F45	Impact of digitalisation				

TABLE 13 - DATA COLLECTION CODE SUMMARY

5.2. Data Analysis

This section will examine each of the five themes that emerged from the data analysis. As seen in the above summary table, these themes are: I- "*Industry 4.0 leads to a shift in the nature of knowledge towards codification*"; II- "*Evidence of a pre-paradigmatic phase in digital manufacturing"*; III- "*Evidence of recognition of a shift on tangible/intangible assets as a source of competitive advantage"*; IV- "*Evidence of limited knowledge and application of protection mechanisms for value appropriation"*; and lastly V- "*Evidence of a lack of awareness of change in the appropriability regimes*".

Furthermore, this section will also provide examples of quotes from the interviewees and the context for the emergence of the first- and second-order codes. Finally, each section will provide a summary table showing the relationship between each theme, second-order code, first-order code and sample quotes.

5.2.1 Data Analysis Theme 1

This section explores the first of the five themes, namely: "Industry 4.0 leads to a shift in the nature of knowledge towards codification". This theme refers to the evidence of a shift from tacit to codified knowledge due to the digitalisation of businesses. The theme covers three main second-order codes which emerged from the interview data, namely:

I- *"There is an acceptance that businesses need to digitalise".* This provides an insight into the interviewee's perspective regarding the need to digitalise*;*

II- "*There is evidence of increased codification of knowledge and an increase in collaborations*". This provides examples of how the interviewees perceive the digitalisation of knowledge within their businesses;

III- III- *"There is recognition that manufacturing is moving towards a knowledge-based economy"*. Finally, this shows how the interviewees see the increased importance of knowledge for manufacturing businesses.

A summary of the theme, first- and second-order codes and the sample quotes is provided in table 14 at the end of this section.

I- "There is an acceptance that businesses need to digitalise"

The businesses interviewed for this research have generally not worked with digital technology to a large extent historically. Rather, the firms have produced physical products with varying embeddedness of digital technology. However, in recent years, firms have started using more digital technology and have an acceptance that their businesses need to be digitalised for the reasons to be discussed below.

Firstly, the participants have expressed a clear perception that the manufacturing industry in general is demanding digitalised businesses and increased use of technology, or products and services that are made possible through the use of digital technologies. According to the interviewees, there is a general pull towards manufacturing digitalisation. As one of the interviewees remarked:

> *"There is an increasing expectation that manufacturers will lead the way in digitalisation. Due to customer demands we expect the majority of products and services to be digitalised over the next five years."* <u>*(Interviewee 002 - Tier 1 Automotive Manufacturing - Sales Director)*</u>

Secondly, this acceptance of the need to digitalise manufacturing can also be seen through the fact that the interviewees voiced concerns with regard to the acquisition of digital skills in manufacturing. There is a common trend towards upskilling and recruiting employees with digital skills, also called digital natives. This demonstrates the recognition of the need to digitalise, but also the lack of skills in the manufacturing businesses currently, as demonstrated by one of the participants:

> *"We are constantly recruiting new people and training our staff to support the manufacturing demand for digital transformation. Having these capabilities in-house will be critical to our success."* <u>*(Interviewee 009 - Logistics, Consultancy & Manufacturing - Operations Director)*</u>

Finally, all the interviewees have demonstrated high levels of activity in relation to ongoing digitalisation programmes at various levels. There is strong evidence that digitalisation is taking centre stage. This suggests a paradigm change in the manufacturing industry, as shown by one of the interviewees:

> *"We have ongoing Industry 4.0 initiatives at local, divisional and group level. This is a topic that comes up in every senior management meeting."* <u>*(Interviewee 001 - Tier 1 Automotive Manufacturing - Managing Director)*</u>

II- "There is evidence of increased codification of knowledge and an increase in collaborations"

The interview data shows that all of the businesses interviewed had participated in collaborations with various actors across their value chains. Nevertheless, the data analysis provides evidence of increased levels of knowledge codification due to the digitalisation of businesses, as well as increased level of collaborations due to the complexity of the new products, technologies and supply chains. The following paragraphs will explore the key reasons attributed to this theme.

Firstly, there is wide recognition by the individuals interviewed that much of their business processes, procedures and knowledge which were typically held in a tacit form in individuals' heads are now being codified into digital solutions such as product life cycle management systems that control all product and process data. This is true even when there is a lack of understanding by the businesses of the consequences of knowledge digitalisation, as expressed by one of the interviewees:

> *"I doubt that we fully understand the consequences of digitalisation to our business beyond operational benefits, but we are actively digitalising everything around us."* <u>*(Interviewee 011 - Engineering/Motorsport - Operations Director)*</u>

Along the same lines, there is strong evidence of new digital tools such as horizontally integrated (across the value chain) product life cycle management software (PLM) being utilised to support manufacturing businesses and their collaborators to design, plan and execute their products and processes. These tools help businesses with knowledge capture and exchange in activities such as collaboration projects. As pointed out by one interviewee, manufacturing businesses are gathering as much information as possible into these systems in order to allow them to reduce their product and process development time:

> *"We have documented most of our current processes and knowledge into the system so that we have a starting point when planning our new processes and operations".* *(Interviewee 007 - Tier 1 Automotive Manufacturing - Operations Director)*

Finally, not only the data for planning products and process, but also all the operational data is being captured and stored in digital format. This is recognised as standard practice for large manufacturers in highly technological fields. However, this is new to Tier 1 and Tier 2 suppliers in the automotive manufacturing industry as explained by an interviewee:

> *"All the operational data which used to be stored in individual spreadsheets is now consolidated into our execution system; from there we know machine parameters and the performance indicators."* *(Interviewee 026 – Manufacturing -Senior Engineer)*

III- "There is recognition that manufacturing is moving towards a knowledge-based economy"

The participants selected for interview are well-seasoned professionals from the manufacturing industry with an average of 18 years of experience in this industry. As such, most interviewees have experienced a manufacturing industry heavily based on tangible assets such as factories, machinery and other "bricks and mortar" assets. Nevertheless, the interview data shows that there is a strong evidence from the participants which demonstrates a move by the manufacturing industry towards a knowledge-based economy, as will be discussed in the next paragraphs.

Firstly, the data analysis shows that there is an increased recognition by the interviewees of business-wide awareness of the importance of knowledge as a source of competitive advantage in manufacturing industry. Some on the interviewees were very vocal about the transition from asset-based advantage to knowledge-based advantage:

> *"Knowledge is critical to our business full stop. The time when we had a competitive advantage because of our facilities or machinery is long gone."* *(Interviewee 009 - Logistics, Consultancy & Manufacturing - Operations Director)*

There is also evidence of manufacturers repositioning and attempting to form alliances and collaborations to support the transition from low to highly knowledge-intensive manufacturing:

> *"We are going through a transition from make-to-print to masters of our own destiny, but we still rely on a lot of R&D activity with partners to acquire the critical knowledge on new products and processes."* *(Interviewee 003 - Tier 1 Automotive Manufacturing - Engineering Director)*

Finally, there is a cross-section of the participants, typically in more strategic roles, that recognise this transition to a knowledge-based economy as a key part of their strategies. This appears to be an industry-wide approach, as explained by an interviewee involved with technology development and funding for the automotive industry:

> *"For a while it has been our plan to focus on high-value manufacturing in the UK. We have plans to support small and large businesses in our region to re-shore high-value, knowledge-intensive products."* *(Interviewee 013 - Auto Manufacturer - R&D Director)*

The following table provides a summary of the themes, codes and quotes discussed in the above section.

Code #	Emerging Themes	Code #	Second Order Codes - Reduced	Code #	First Order Codes	Quote #	Interview Extracts
T1	Industry 4.0 leads to shift in the nature of knowledge towards codification	S1	There is an acceptance that businesses need to digitalise	F1	The industry is demanding digitalised businesses	Q1	*"There is an increasingly expectation that manufactures will lead the way in digitalisation. Due to customer demands we expect the majority of products and services to be digitalised over the next 5 years."*
				F2	Demand for digital skills and digital natives	Q2	*"We are constantly recruiting new people and training our staff to support the manufacturing demand for digital transformation. Having these capabilities in-house will be critical to our success."*
				F3	On-going Digitalisation programmes	Q3	*"We have on-going industry 4.0 initiatives at local, divisional and group level. This is a topic that comes up in every senior management meeting."*
		S2	There is evidence of increased codification of knowledge and increase in collaborations	F4	Digitalisation of knowledge	Q4	*"I doubt that we fully understand the consequences of digitalisation to our business beyond operational benefits, but we are actively digitalising everything around us."*
				F5	New digital tools for planning	Q5	*"We have documented most of our current processes and knowledge into the system so that we have a starting point when planning our new processes and operations".*
				F6	New digital tools for execution	Q6	*"All the operational data which used to be stored in individual spreadsheets is now consolidated into our execution system, from there we know machine parameters and the performance indicators."*
		S3	There is a recognition that manufacturing is moving towards a knowledge based economy	F7	Awareness of importance of knowledge	Q7	*"Knowledge is critical to our business full stop. The time when we had a competitive advantage because of our facilities or machinery is long gone."*
				F8	Increase in R&D activities	Q8	*"We are going through a transition from make to print to masters or our own destiny but, we still rely on a lot of R&D activity with partners to acquired the critical knowledge on new products and processes."*
				F9	Moving into high-value manufacturing	Q9	*"For a while it has been our plan to focus on high-value manufacturing in the UK. We have plans to support small and large businesses in our region to re-shore high-value, knowledge intensive products."*

TABLE 14 - THEME 1 AND RELATED CODES WITH SINGLE EXAMPLE QUOTES FROM INTERVIEWEES

5.2.2 Data Analysis Theme 2

This section explores the second of the five themes, namely: "Evidence of a pre-paradigmatic phase in the adoption of I4.0 in manufacturing businesses." This theme refers to the data analysis results which point out the lack of a clear paradigm with established actors, technologies and value distribution models in the manufacturing supply chain. This theme covers three main second-order codes which emerged from the interview data, namely:

I- *"There is a general lack of clarity on the value of digitalisation for manufacturing".* This demonstrated the interviewees' perspective regarding the expected value of digitalisation to manufacturing businesses*;*

II- "*There is uncertainty regarding 'risks and benefits' of digitalisation of manufacturing*". This section provides examples of how the interviewees perceive the potential risks and benefits derived from the digitalisation of their businesses;

III- *"There are no real examples to demonstrate horizontal integration in manufacturing"*. Finally, this shows the perceived lack of real-life examples of both risks and benefits which are supposedly emanating from the digitalisation of manufacturing businesses.

In the same fashion as in the previous section, a summary of the theme, first- and second-order codes and the sample quotes is provided in table 15 at the end of this section.

I- "There is a general lack of clarity on the value of digitalisation for manufacturing"

Despite the fact that all businesses from which the interviewees were selected are involved in digitalisation programmes, the data analysis strongly indicates that there is a consensus between the participants that there is a general lack of clarity on the value of digitalisation for manufacturing businesses. The following paragraphs will explore the key reasons put forward by the interviewees.

The data analysis shows that the majority of interviewees are unclear about the claimed impact of digitalisation on manufacturing business efficiency. Many participants demonstrated a level of doubt in regard to industry publications with very ambitious claims on operational benefits. One of the interviewees, a senior leader of a large manufacturing business, stated:

> *"We have all been bombarded with information from consulting companies and service providers telling us the double-digit operational benefits to be achieved, but I am not entirely*

sure how robust these estimations are." *(Interviewee 004 - Tier 1 Automotive Manufacturing - Commercial Director)*

Nevertheless, even when the value of digitalisation for manufacturing businesses is uncertain, the data analysis shows that the interviewees perceive a certain value in the adoption of digitalisation as a basic requirement for the manufacturing industry. One of the participants, drawing a parallel with lean initiatives and industry accreditations, described his views as:

> *"I feel like the customers will expect digital integration as a set of basics in place. Just like we have an expectation on lean processes and certain accreditations in order to even get an invitation for bidding."* *(Interviewee 002 - Tier 1 Automotive Manufacturing - Sales Director)*

Lastly, despite the uncertainty regarding the value of digitalisation, there is a common positive outlook across a section of the manufacturing leaders interviewed who share high expectations regarding the potential value derived from business growth through manufacturing digitalisation. One of the interviewees, a senior manager in the sales function of a large technology provider for the manufacturing industry, described his expectation in terms of early adoption of manufacturing digitalisation:

> *"Having a time advantage in the digital implementation in comparison to our competitor will allow us to grow not only the current products, but also new product ranges which will benefit from the streamlined and digitalised processes across our business."* *(Interviewee 013 - Auto Manufacturer - R&D Director)*

II- "*There is uncertainty regarding 'risks and benefits' of digitalisation of manufacturing*"

The data analysis shows further uncertainty regarding the interviewees' positions on the risks and benefits of adoption of digitalisation in manufacturing. The uncertainty appears to be accentuated by the lack of a business case, the speed of technological development and the industry-wide limited understanding of the technologies being deployed. The next paragraphs will explore some of the views expressed by the participants.

Firstly, the data analysis shows evidence of investment in digitalisation projects despite the level of uncertainty and financial justification. According to some of the participants, this approach is atypical of the manufacturing industry, which has financial limitations and demands a clear business case for investment. One of the participants, a senior manager in the finance department of a large manufacturer, commented:

> *"The main issue with our digitalisation projects is the lack of clarity on our business case. It is very difficult to estimate where these technologies will take us. For example, if I use AI for predictive maintenance, but fail to change the processes around it, the benefit will be limited."* *(Interviewee 012 - Engineering/Motorsport - Engineering Director)*

There is also evidence of mixed views in regard to risks related to early adoption or delayed adoption of digital technologies. One of the interviewees, a lead engineer for a manufacturing business, described his view:

> *"Things are moving too fast in this space and I feel like we don't know how it is going to impact us or the risks of acting too quickly and implementing an obsolete solution. Also the risk of inaction is unclear."* *(Interviewee 005 - Tier 1 Automotive Manufacturing - Strategy Director)*

Finally, on a similar note, a reoccurring theme that could be associated with the uncertainty of risks and benefits to manufacturers is the participants' views of the speed of technological development. As a senior information technology manager for a manufacturing technology provider described it:

> *"There is too much going on and the businesses are not able to keep up. I also see an issue with education institutions who are not keeping up with the latest technologies and the new engineers are not prepared to make full use of the Industry 4.0 technologies.* *(Interviewee 001 - Tier 1 Automotive Manufacturing - Managing Director)*

III- "There are no real examples to demonstrate horizontal integration in manufacturing"

Perhaps a very important contributing factor to the level of uncertainty regarding the value, risks, and benefits of digitalisation of the manufacturing industry can be attributed to trends emerging from the interview data and the lack of real examples to demonstrate horizontal integration of manufacturing value chains. The most prominent reasons for this were evidenced in the following data.

There was a common reoccurring theme from a large number of interviewees who reported a similar phenomenon. In essence they have all seen the application of individual digital technologies in a semi-discrete manner within single businesses (what is referred to in the Industry 4.0 literature as vertical integration), but as a senior technology leader from a large manufacturer described:

> *I have seen a few businesses that have digitalised their internal processes, like the Siemens Congleton factory, but I am yet to see a real-life example of full integration of the manufacturing supply chain from end to end.”* *(Interviewee 011 - Engineering/Motorsport - Operations Director)*

Another reoccurring perspective very common with Tier 1 and Tier 2 manufacturers is that the few case studies available are not directly relatable to their businesses and operations. As one of the interviewees from a UK Tier 2 manufacturer describes it:

> *"There is a lack of case studies to help the small and medium manufacturers trying to kick off their digitalisation initiatives. We can find stuff from the likes of GE, Bosch and Siemens, but we are worlds apart in terms of operations."* *(Interviewee 022 - Tier 1/2 Automotive Manufacturing - Senior Engineer)*

Lastly, there is also a general uncertainty expressed in regard to wider digitalisation benefits from those in the manufacturing industry who have already implemented localised digital technologies. As the quote below demonstrates, localised operational benefits can be found, but as the interviewee describes, there is a “struggle” to understand the wider benefits:

> *"Within our group of companies there are many examples of operational benefits where we have used technology such as collaborative robots and automation, but I have not seen anything yet on supply chain benefits. I even struggle to think how this would benefit use."* *(Interviewee 007 - Tier 1 Automotive Manufacturing - Operations Director)*

Code #	Emerging Themes	Code #	Second Order Codes - Reduced	Code #	First Order Codes	Quote #	Interview Extracts
T2	Evidence of preparadigmatic phase in digital manufacturing	S4	There is a general lack of clarity on the value of digitalisation for manufacturing	F10	Impact on operational Efficiency	Q10	*"We have all been bombarded with information from consulting companies and service providers telling us the double digit operational benefits to be achieved, but I am not entirely sure how robust this estimations are."*
				F11	Impact on customer relations	Q11	*"I feel like the customers will expect digital integration as set of basics in place. Just like we have an expectation on lean processes and certain accreditations in order to even get an invitation for bidding."*
				F12	Potential business growth	Q12	*"Having a time advantage in the digital implementation in comparison to our competitor will allow us to grow not only the current products, but also new product ranges which will benefit from the streamlined and digitalised processes across our business."*
		S5	There is uncertainty regarding “risks and benefits” of digitalisation of manufacturing	F13	Unsure of the short term benefits	Q13	*"The main issue with our digitalisation projects is the lack of clarity on our business case. It is very difficult to estimate where these technologies will take use. For example if I use AI for predictive maintenance, but fail to change the processes around it the benefit will be limited."*
				F14	Risk awareness is limited	Q14	*"Things are moving to fast in this space and I feel like we don't know how it is going to impact us or the risks of acting too quick and implementing an obsolete solution. Also the risk of inaction is unclear."*
				F15	Difficulties with the speed of change	Q15	*"There is too much going on and the businesses are not able to keep-up. I also see an issue with education institutions who are not keeping up with the latest technologies and the new engineers are not prepared to make full use of the industry 4.0 technologies."*
		S6	There are no real examples to demonstrate Horizontal Integration in manufacturing	F16	Real life examples	Q16	*"I have seen a few businesses that have digitalise their internal processes like the Siemens Congleton factory, but I am yet to see a real life example of full integration of the manufacturing supply chain from end-to-end.*
				F17	Limited case studies	Q17	*"There is a lack of case studies to help the small and medium manufacturers trying to kick off their digitalisation initiatives. We can find stuff from the likes of GE, Bosh and Siemens, but we are worlds apart in terms of operations."*
				F18	Examples of localised operational benefits	Q18	*"Within our Group of companies there are many examples of operational benefits where we have used technology such as cobots and automation, but I have not seen anything yet on supply chain benefits. I even struggle to think how this would benefit use."*

TABLE 15 - THEME 2 AND RELATED CODES WITH SINGLE EXAMPLE QUOTES FROM INTERVIEWEES

5.2.3 Data Analysis Theme 3

This section explores the third of the five themes, namely: "Evidence of recognition of a shift on tangible/intangible assets as a source of competitive advantage". This theme refers to the emerging data pointing out that there was a clear recognition by the interviewees that the manufacturing industry is going through a transition from an industry where competitive advantage is heavily based on tangible assets, to one where competitive advantage can only be based on intangible assets. This will be explored in the following discussion covering the three main second-order codes which emerged from the interview data, namely:

I- *"There is evidence of increased knowledge of transfer collaborations".* This section provides an insight into the perceived increase of collaboration where digitalised knowledge is being exchanged between the manufacturers collaborating in a given project;

II- "*There is uncertainty as to how digitalisation will affect BMs for manufacturers, but there is recognition that intangible assets are increasingly important*". This provides examples of how the interviewees perceive the increased importance of intangible assets in manufacturing businesses, even when they believe that the overall business models will not be affected;

III- III- *"There is recognition that knowledge and intellectual property is key to competitive advantage"*. Finally, this section provides evidence of increased reliance on intangible assets and intellectual property as a source of differentiation and competitive advantage to manufacturing businesses.

A summary of the theme, first- and second-order codes and the sample quotes is provided in table 16 at the end of this section.

I- "There is evidence of increased knowledge transfer collaborations."

Despite the fact that a large portion of the manufacturing businesses interviewed are usually involved in collaboration projects in their value chains, there is a trend emanating from the data analysis pointing out a perceived increase in the level of collaborations where knowledge is the main currency exchanged in the project. The following paragraphs will show some of the reasons for this change.

There is a perception by the participants that there is more data being shared with customers, suppliers and collaborators in general. This position was highlighted by a senior technology manager for a large manufacturing business involved in collaboration projects, who expressed the following view:

> *"Our teams are increasingly sharing planning and operational data in every project. We believe that sharing more data with customers, suppliers and collaborators will improve our offerings."* *(Interviewee 023 - Tier 1/2 Automotive Manufacturing - Senior Buyer)*

The data analysis suggests that in many cases the relevant manufacturing technology has already been developed by other businesses in the same or even in different industries. According to the participants, in some of the cases, high-volume manufacturers and technology providers already rely on digital technologies which can be leveraged across the value chain, e.g. OEMs' executions systems and product designers' product life cycle management systems. As can be seen from some of the interviews, collaborations to exchange knowledge are increasingly common and digitalisation contributes to knowledge transfer:

> *"Ninety per cent of our new products are developed through collaborations where we share our knowledge and know-how with the partners, and they do the same. Digitalisation helps a lot with this sharing."* *(Interviewee 005 - Tier 1 Automotive Manufacturing - Strategy Director)*

A final characteristic emanating from the data analysis as pointed out by a number of interviewees is that collaborations are being strategically planned in order to bring in partners with a specific knowledge base already formed, rather than any partner with general skills and capability to develop new knowledge during the collaboration, as explained by one of the participants:

> *"Before we used to collaborate with anyone to develop the knowledge together. Nowadays we are increasingly targeting potential partners with the knowledge base already formed."* *(Interviewee 029 - Technology Centre - Senior IT manager)*

II- *"There is uncertainty as to how digitalisation will affect BMs for manufacturers, but there is recognition that intangible assets are increasingly important."*

Most manufacturing businesses taking part in the interviews have a very clear and traditional business model. However, in line with the uncertainty regarding the impact of digitalisation in other aspects of manufacturing, there is a high level of uncertainty regarding the impact of digitalisation on current and future manufacturing business models.

Nevertheless, the data analysis shows a clear recognition that intangible assets are more important to manufacturers in the face of digitalisation. The next paragraphs will cover some of the insights from the data analysis.

A small proportion of the participants believe that due to the long-term contractual agreements typical of the automotive manufacturing industry, their business models will remain unaffected in the short term. However, contradictorily the same interviewees believe that intangible assets and intellectual property will become more important to their businesses, as stated by a commercial director of a larger manufacturing business:

> *"I don't think our current business model will be impacted as we are tied up in long-term contracts. On the other hand, I would think that IP will become a lot more important to the negotiation of future contracts."* *(Interviewee 003 - Tier 1 Automotive Manufacturing - Engineering Director)*

There is a consensus amongst the majority of interviewees that their business models will be completely transformed, and their focus will change to digital and intellectual assets, as expressed by an information technology director of a large manufacturer:

> *"Digitalisation will completely change our business models. We are currently setting up a new business where the barriers to entry will be solely based on our digital infrastructure and on our intellectual property."* *(Interviewee 014 - Auto Manufacturer - R&D Director)*

Finally, intellectual property has been identified as more important due to digitalisation, as it is seen as a potential barrier to entry and a source of competitive advantage directly linked to business performance. One of the interviewees, a senior manufacturing manager at a larger automotive manufacturing company, commented:

"The IP in our brand and product is critical today. We are owned by a Chinese company and they always emphasise the importance of our IP in our design and trademarks as the most critical asset, both home and abroad." *(Interviewee 028 – Manufacturing - Project Manager)*

III- "There is recognition that knowledge and intellectual property is key to competitive advantage."

Despite the fact that manufacturers in the automotive industry have relatively less registered IP than other industries, e.g. technology and aerospace, there is clear evidence that the interviewees consider intellectual property (registered and informal) as a critical part of their value offering and as a source of competitive advantage. The following sections will explore the key reasons attributed to this trend by the interviewees.

Firstly, most participants expressed a view that technology in the manufacturing sector is decreasing in cost, and this fact lowers the barrier to entry, stripping away some of their traditional sources of competitive advantage. This is perhaps one of the main contributing factors to the increased interest in intangible assets as an alternative source of competitive advantage. As pointed out by a managing director of a large manufacturer:

"Intangible assets are the main differentiator and source of competitive advantage in this environment where technology is becoming increasingly cheap and knowledge is available at the tip of your fingers." *(Interviewee 018 - Intellectual Property/Legal - Director)*

Intellectual property is also seen as an alternative to traditional differentiators such as cost and quality, which can lead to a reduction in margins in a highly competitive and saturated market such as automotive manufacturing. A legal advisor to various manufacturers and technology developers expressed the following view:

"We aim to support manufacturers and the other partners in the collaboration projects by demonstrating how IP is the single most important source of differentiation in the saturated automotive manufacturing industry." *(Interviewee 017 - Intellectual Property/Legal - Manager)*

Finally, the majority of participants expressed the view that intellectual-property-based assets are currently very important to manufacturers. Some interviewees also pointed out that this will only increase with digitalisation due to customers’ purchasing practices, which will benefit from the wide range of data and information available in the digitalised world. As one of the participants noted:

> *"I cannot stress enough how important IP is for our business today, as it is the main reason we form our partnerships and joint ventures, but even more so in the future where everything we do will be digitalised and available to our customers."* *(Interviewee 006 - Tier 1 Automotive Manufacturing - Engineering Manager)*

Code #	Emerging Themes	Code #	Second Order Codes - Reduced	Code #	First Order Codes	Quote #	Interview Extracts
T3	Evidence of recognition of a shift on tangible/intangible asset as source of competitive advantage	S7	There is evidence of increased knowledge transfer collaborations	F19	Increase in collaborations exchanging data	Q19	*"Our teams are increasingly sharing planning and operational data in every project. We believe that sharing more data with customers, suppliers and collaborators will improve our offerings".*
				F20	Knowledge intensive collaboration	Q20	*"Ninety per cent of our new products are developed through collaborations were we share our knowledge and know-how with the partners and they do the same. Digitalisation helps a-lot with this sharing."*
				F21	Increasingly targeted collaborations	Q21	*"Before we used to collaborate with anyone to develop the knowledge together. Now-a-days we are increasingly targeting potential partners with the knowledge based already formed."*
		S8	There is uncertainty as to how digitalisation will affect BMs for manufacturers, but there is recognition that intangible assets are increasingly important	F22	No business model impact	Q22	*"I don't think our current business model will be impacted as we are tied up in long term contracts. On the other hand, I would think that IP will become a lot more important to the negotiation of future contracts."*
				F23	Digitalisation will change our business models	Q23	*"Digitalisation will completely change our business models. We are currently setting up a new business where the barriers to entry will be solely based on our digital infrastructure and on our Intellectual Property."*
				F24	Intangible assets importance	Q24	*"The IP in our brand and product is critical today. We are owned by a Chinese company and they always emphasise the importance of our IP in our design and trademarks as the most critical asset, both home and abroad"*
		S9	There is recognition that knowledge and intellectual property is key to competitive advantage	F25	Intangible assets for competitive advantage	Q25	*"Intangible assets are the main differentiator and source on competitive advantage in this environment where technology is becoming increasingly cheap and knowledge is available at the tip of your fingers."*
				F26	Intangible assets for differentiation	Q26	*"We aim to support manufacturers and the other partners in the collaboration projects by demonstrating how IP is the single most important source of differentiation in the saturated automotive manufacturing industry."*
				F27	Intellectual Property importance	Q27	*"I cannot stress enough how important IP is for our business today, as it is the main reason we form our partnerships and joint ventures, but even more so in the future where everything we do we be digitalised and available to our customers."*

TABLE 16 - THEME 3 AND RELATED CODES WITH SINGLE EXAMPLE QUOTES FROM INTERVIEWEES

5.2.4 Data Analysis Theme 4

This section explores the penultimate of the five themes, namely: "Evidence of limited knowledge and application of protection mechanisms for value appropriation". It will explore the fact that despite the above recognition of the change from tangible to intangible asset-based advantages and the increased importance of intellectual property as a source of competitive advantage in manufacturing, the data analysis presents evidence of limited knowledge and application of protection mechanisms for value appropriation amongst the participants. This theme covers three main second-order codes which emerged from the interview data, namely:

I- *"There is evidence that manufacturing businesses typically use a very narrow definition of IP."* This provides an insight into the interviewees' perspective on the definition and interpretation of intellectual property*;*

II- "*There is evidence that manufacturing businesses do not have an IP strategy to protect innovation.*" The data indicates that there is a semi-casual approach to intangible asset protection and intellectual property registration, thus indicating that most manufacturers interviewed do not have an intangible asset protection strategy;

III- III- *"There is recognition that IP knowledge should be decentralised to all functions."* Finally, there is some evidence of an acceptance by the interviewees that, in order to effectively protect intellectual property, all departments must be aware of and responsible for taking steps to identify and protect intangible assets.

A summary of the theme, first- and second-order codes and the sample quotes is provided in Table 17 at the end of this section.

I- "There is evidence that manufacturing businesses typically use a very narrow definition of IP."

As discussed in the introduction to this thesis and explored in detail as part of the literature review, intellectual property is a very broad term and includes formal and informal, registered and unregistered types of intangible asset. Nevertheless, this section will provide an example of the narrow definition of intellectual property as perceived by most interviewees. The following paragraphs will explore the key reasons attributed by the interviewees who very often only recognise registered IP, which is typically very costly and very rarely utilised for protection.

Firstly, a large portion of the participants, when asked about intellectual property ownership, could easily refer to formal and registered methods, but most failed to identify other forms of IP such as trade secrets, which are the most prevalent form of IP amongst manufacturers. The following was a statement provided by a senior commercial manager working for a large manufacturer:

> *"Yes, we own IP. I think we own three or four patents and trademark protection on our name, logo and branding. There is not an awful lot of IP, but we survived over the last three decades just fine."* _(Interviewee 010 - Logistics, Consultancy & Manufacturing - Senior Manager)_

There is also evidence of manufacturers interpreting intellectual property in the light of the requirement for patent registration, which demands a level of novelty and inventiveness to warrant the patent monopoly for a fixed period of time (further information on patent requirements was discussed in the literature review chapter). The following quote from a senior finance manager of a Tier 1 manufacturer illustrates this view:

> *"We don't have much IP in this business, most of what we do is common to other Tier 1 manufacturers and everyone knows about it. In the future we will get into more product design and maybe we will look at options to protect the new IP."* _(Interviewee 002 - Tier 1 Automotive Manufacturing - Sales Director)_

Finally, perhaps due to this narrow interpretation of intellectual property only in its formal and registered form, there is a cross-section of the interviewees, typically those who have limited experience in IP ownership, who perceive IP as a time-consuming and costly activity, as the following quote from an automotive manufacturer innovation manager demonstrates:

> *"The costs of IP protection are too prohibitive, and it also takes too long. I am not sure whether we would even be able to protect anything with our current contractual agreements and no budget."* _(Interviewee 022 - Tier 1/2 Automotive Manufacturing - Senior Engineer)_

II- "*There is evidence that manufacturing businesses do not have an IP strategy to protect innovation.*"

The data analysis shows that, despite the fact that most participants indicated that their businesses own registered intellectual property rights, there is clear evidence that most manufacturers do not have a strategy for intangible asset protection. Furthermore, there is also an indication that most decisions related to IP protection are made at centralised functions such as a legal team located at a parent company or even external legal advisors in cases where the manufacturing business outsources specialised legal services. The following paragraphs will explore some of the information describing the participants' position regarding IP strategy.

Most participants have described a centralised approach to intellectual property protection. The typical configuration according to the interviewees appears to be one where most decisions regarding intangible asset protection are made at a centralised legal department. Such a position is applicable with regards to IP in all types of relationships, from supplier agreements, collaboration agreements and customer agreements. The following statement was provided by a senior engineer responsible for collaboration projects for a large manufacturer:

> *"We have a legal team that reviews all of our contractual agreements and I believe that one of the lawyers is responsible for IP. Other than that, there is no strategy as such to define things to protect or to give away."* *(Interviewee 004 - Tier 1 Automotive Manufacturing - Commercial Director)*

Some of the interviewees have expressed the view that IP is critical to their businesses. This position is very strong at the OEM level, but the data has shown that the wider supply chain takes a more casual approach to IP. As a senior commercial manager from an automotive manufacturer described:

> *"Ownership of IP is critical to our business. We need to ensure the protection of both our brand and our operations, so we ensure that ownership of IP in collaborations and supply agreements always sits with us."* *(Interviewee 007 - Tier 1 Automotive Manufacturing - Operations Director)*

Finally, to further illustrate the lack of intellectual property strategy and the level of protection in the supply chain, one can refer to a passage from a senior manager responsible for innovation at a Tier 2 automotive manufacturer:

> *"We have been involved in over 10 collaboration projects over the past four to five years, but there is nobody looking after IP. I think that the university partner has registered a couple of patents, but we didn't get anything."* *(Interviewee 008 - Tier 1 Automotive Manufacturing - Financial Director)*

III- "There is recognition that IP knowledge should be decentralised to all functions"

The participants demonstrated an increased concern regarding the lack of intellectual property knowledge at the point of use. Some voiced strong views that engineers, particularly those involved in collaboration projects, should be more capable in this area. There is also a common view expressed by most interviewees that intellectual property should be decentralised to local teams, rather than a central legal function. The following paragraphs will explore the key reasons attributed by the interviewees.

The data analysis points out that most of the participants believe there is a need to improve their businesses knowledge regarding intellectual property. Such a need is associated with concerns regarding the effective protection of relevant manufacturing IP. The following quote was provided by a manufacturing director from a large automotive business:

> *"We definitely need to increase our knowledge of IP law. I feel like the lawyers lack our manufacturing knowledge in operations and commercials, so it is difficult to apply the law in isolation."* *(Interviewee 001 - Tier 1 Automotive Manufacturing - Managing Director)*

There is a general acknowledgement by the participants regarding the skills gap in intellectual property. Furthermore, there is also strong evidence of manufacturers taking action to address the education challenges in this area. As a technology director from a large manufacturer described:

"Our team is going to be trained in intellectual property as a matter of urgency. We cannot afford to have engineers sharing our latest inventions with the customers; we all lack education in this area." *(Interviewee 012 - Engineering/Motorsport - Engineering Director)*

Lastly, due to the perceived increase in the importance of intellectual property for manufacturers digitalising their current and new businesses, there is evidence of a desire by manufacturers to control aspects of IP management locally rather than centrally, as mentioned by a commercial director of a manufacturing business (part of a larger manufacturing group of companies):

"All the IP matters are resolved at group level; we don't have a local legal team to manage our IP. Maybe we should change this as IP is more important than ever for our new business." *(Interviewee 027 – Manufacturing - Senior Engineer)*

Code #	Emerging Themes	Code #	Second Order Codes - Reduced	Code #	First Order Codes	Quote #	Interview Extracts
T4	Evidence of limited knowledge and application of protection mechanisms for value appropriation	S10	There is evidence that manufacturing businesses typically use a very narrow definition of IP	F28	Registered Intellectual Property	Q28	*"Yes, we own IP. I think we own three or four patents and trademark protection on our name, logo and branding. There is not an awful lot of IP, but we survived over the last 3 decades just fine."*
				F29	Intellectual Property for protection	Q29	*"We don't have much IP in this business, most of what we do is common to other tier 1 manufacturers and everyone knows about it. In the future we will get into more product design and maybe we will look at options to protect the new IP."*
				F30	Intellectual Property costs	Q30	*" The costs of IP protection are too prohibitive and it also takes too long. I am not sure whether we would even be able to protect anything with our current contractual agreements and no budget."*
		S11	There is evidence that manufacturing Businesses do not have an IP strategy to protect innovation	F31	No Intellectual Property Strategy	Q31	*"We have a legal team that reviews all of our contractual agreements and I believe that one of the lawyers is responsible for IP. Other than that, there is no strategy as such to define things to protect or to give away."*
				F32	Intellectual Property Ownership	Q32	*"Ownership of IP is critical to our business. We need to ensure the protection of both, or brand and our operations, so we ensure that ownership of IP in collaborations and supply agreements always sits with us."*
				F33	Intellectual Property in Innovation projects	Q33	*"We have been involved in over 10 collaboration projects over the past four to five years, but there is nobody looking after IP. I think that the University partner has registered a couple of patents, but we didn't get anything."*
		S12	There is recognition that IP knowledge should be decentralised to all functions	F34	Intellectual Property Law	Q34	*"We definitely need to increase our knowledge of IP law. I feel like the lawyers lack our manufacturing knowledge in operations and commercials so it is difficult to apply the law in isolation."*
				F35	Intellectual Property Education	Q35	*"Our team is going to be trained in Intellectual Property as a matter of urgency. We cannot afford to have engineers sharing our latest inventions with the customers, we all lack education in this area."*
				F36	Intellectual Property Management	Q36	*"All the IP matters are resolved at group level, we don't have a local legal team to manage our IP. Maybe we should change this as IP is more important than ever for our new business."*

TABLE 17 - THEME 4 AND RELATED CODES WITH SINGLE EXAMPLE QUOTES FROM INTERVIEWEES

5.2.5 Data Analysis Theme 5

This section explores the final of the five themes, namely: "Evidence of lack of awareness of change in the appropriability regimes." This theme refers to the theoretical underpinnings of the other four themes and links the data analysis to the theory of appropriability regimes.

The appropriability regime mainly depends on legal and technological factors. On one hand, the realisation of rents from innovation depends on strong or effective intellectual property rights (IPR) protection by the legal system. On the other hand, characteristics of technology, such as degree of codification, complexity, and ease of reverse engineering, determine the height of barriers to imitation, which in turn affects the ease with which rivals can imitate the innovation.

This section will explore the data, demonstrating that most participants and their manufacturing businesses are unaware of the changes in appropriability regimes due to the digitalisation of businesses and value chains. The section will cover three main second-order codes which emerged from the interview data, namely:

I- *"There is uncertainty as to how digitalisation will affect BMs for manufacturers."* This section provides a brief demonstration of the participants' perceptions regarding the changes in manufacturing value propositions*;*

II- "*Manufacturing businesses typically use a very narrow definition of IP as a protection mechanism, but not as a source of revenue.*" In this section examples of the data analysis regarding the manufacturers' approach to intellectual property are discussed.

III- III- *"There is no evidence of manufacturers adapting their IP strategies due to digitalisation".* Lastly, this section explores some of the participants' views regarding the need to adapt or adopt intellectual property for manufacturing businesses in the face of changes introduced by digitalising manufacturing.

A summary of the theme, first- and second-order codes and the sample quotes is provided in table 18 at the end of this section.

I- "There is uncertainty as to how digitalisation will affect BMs for manufacturers."

The data analysis show that as manufacturers move into digitalised businesses, there is a recognition that they are required to upskill the workforce, not only in regard to digital technologies, but also on areas and functions affected by digitalisation. The interviewees have demonstrated their business's intentions to re-align internal resources and competences in line with the new digital technologies. However, for many of the participants, there is a high level of uncertainty regarding the impact of digitalisation on their business models (as already discussed above in section 5.2.3). The next few paragraphs will show a few data samples from the analysis.

There was a recurring theme amongst the participants in respect of changes to value generation and appropriation in the digitalised manufacturing value chain. Some of the interviewees from the lower tiers in the value chain demonstrated a level of concern with regards to appropriation of value due to digitalisation, as described by a finance director of a large manufacturer:

> *"I think most of our team would agree that with digitalisation it will become more difficult to protect our margins and the value in the current products, as the customers will be able to see everything; there will be nowhere to hide any bounce."* *(Interviewee 004 - Tier 1 Automotive Manufacturing - Commercial Director)*

Some of the data points out that there is an expectation of changes to businesses models. There is also evidence of businesses taking steps to adapt their businesses in order to take advantage of changes in the industry. There is a particular level of emphasis on the value propositions offered by traditional manufacturers:

> *"Digitalisation will change our industry. We are looking to adapt and seek opportunities in products and services and with a number of potential add-ons to customers and end-users."* *(Interviewee 013 - Auto Manufacturer - R&D Director)*

Finally, there is evidence of an increased level of uncertainty regarding the future position of manufacturers in the value chain in respect of suppliers and customers. There is a cross-section of the interviewees, typically from externally facing functions (for example sales and purchasing), that recognise that an element of supply chain repositioning is taking place alongside the transition into digital manufacturing. Some of this re-positioning can be attributed to the fact that digitalisation facilitates information and knowledge exchange across the value chain, which in turn increases the risk of imitation by other manufacturers with similar skills and capabilities in the same value chain. One of the participants, a strategy director to a large manufacturer, explained his views:

> *"One way to look at it is that further connectivity with our suppliers and customers will enhance our relationships. The other is that the customers could bypass us completely and go straight to the suppliers themselves. This is not new in automotive manufacturing, but digitalisation could increase it."* *(Interviewee 007 - Tier 1 Automotive Manufacturing - Operations Director)*

II- "*Manufacturing businesses typically use a very narrow definition of IP as a protection mechanism, but not as a source of revenue.*"

According to the data analysis, all participants own intellectual property rights at least in the registered form. Nevertheless, a large number of interviewees make only reference to registered IP (patents, trademarks and registered design), failing to mention any other form of intangible assets (copyrights, trade secrets, contractual covenants, etc.). There was also an emphasis on using IP as a protection mechanism, but very few see it as a source of revenue.

There is clear evidence from the data analysis that most of the interviewees have awareness of intellectual property benefits as a protection mechanism to defend their businesses from imitation. Nevertheless, as in the following quote from a director of a large manufacturing business, there is still some uncertainty regarding the ability to enforce IP rights:

> *"We only use patents to protect our inventions, so that if a competitor tries to imitate our products we will go after them and make sure we stop it. The thing I am not sure of is whether we can identify people using or imitating our product."* *(Interviewee 026 - Manufacturing - Senior Engineer)*

Another trend amongst the participants was lack of awareness of intellectual property as a source of revenue to support the manufacturing businesses. However, as in the following quote, some of the interviewees have demonstrated an interest in using IP as a source of revenue:

"We have patents and trademarks, but we never made any money with it. I think that we should be more like other businesses who license some of their IP to generate revenue." *(Interviewee 001 - Tier 1 Automotive Manufacturing - Managing Director)*

Lastly, this limited and narrow interpretation of intellectual property, which is limited to registered IP and is only used to protect manufacturers from imitation by competitors, can be perhaps associated with a lack of understanding of other IP benefits such as brand recognition and as a valuable asset in knowledge exchange collaborations, as pointed out by an interviewee involved with technology development and funding for the automotive industry:

"There are businesses out there using IP as a currency in kind to enter into collaborations and even joint ventures, but most of the Tier 1 manufacturers we work with in the UK are missing this opportunity." (Interviewee 024 - Intellectual Property/Legal - Senior Manager)

III- "There is no evidence of manufacturers adapting their IP strategies due to digitalisation."

Despite the participants' recognition that intangible assets are increasingly important to manufacturers as discussed above, there is still a lag in terms of any recognition of the need to adapt or even adopt an IP strategy in the face of the aforementioned changes introduced by the digitalisation of manufacturing businesses. The next few paragraphs will illustrate the interviewees' perspective on manufacturing IP strategy in the context of digitalisation.

As previously mentioned in section 5.3.4, some of the participants have indicated that their businesses have a narrow definition of IP and fail to provide a strategy to protect their innovations. The data analysis shows that this is also true of digital innovations and the knowledge exchange across the value chain. The following quote by a commercial director of an automotive manufacturer illustrates a very common approach:

"We don't have an intellectual property strategy as such; it is typically the business strategy that guides everything else, so if a particular business generates some IP we will try to protect it." *(Interviewee 008 - Tier 1 Automotive Manufacturing - Financial Director)*

Some participants have contradicted themselves during the interview first by describing that digitalisation will bring vast amounts of change to their businesses, but later describing no need to adapt their business models or intellectual property strategies. Furthermore, some interviewees have linked the need for change in strategy to a potential market pull, which has not yet manifested itself, as pointed out by one of the participants sharing this view:

> *"I don't think we will be adapting our strategies; the law is not changing, so in a way it will be the same rules. As always we will strive to comply with the OEM requirements and terms and conditions."* *(Interviewee 002 - Tier 1 Automotive Manufacturing - Sales Director)*

Finally, there is a cross-section of the interviewees, typically individuals at the most senior level with strategic responsibility, that recognise the impact of digitalisation in the current manufacturing value appropriation paradigm and even link it to scenarios with potential risks regarding competitors and customers. An example of this scenario analysis was posed by a finance director of a Tier 1 manufacturer:

> *"...there are scenarios where we can see companies entering our industry without having any knowledge of our product or processes but are just utilising our product and process data and machine learning. In the same way, customers will be able to reverse-engineer our costs and squeeze our margins even further."* *(Interviewee 022 - Tier 1/2 Automotive Manufacturing - Senior Engineer)*

Having explored each of the five themes that emerged from the data analysis in turn, by providing examples of quotes illustrating the links between the interview excerpts, the first- and second-order codes and finally the themes, attention will now turn to how this data was combined into three case studies in order to validate and reference data collected through the other methods explained in the data collection chapter.

Code #	Emerging Themes	Code #	Second Order Codes - Reduced	Code #	First Order Codes	Quote #	Interview Extracts
T5	Evidence of lack of awareness of change in the appropriability regimes	S13	There is uncertainty as to how digitalisation will affect BMs for manufacturers	F37	Changes to value generation and distribution	Q37	*"I think most of our team would agree that with digitalisation it will become more difficult to protect our margins and the value in the current products as the customers will be able to see everything, there will be nowhere to hide any bounce."*
T5	Evidence of lack of awareness of change in the appropriability regimes	S13	There is uncertainty as to how digitalisation will affect BMs for manufacturers	F38	Changes to value proposition	Q38	*"Digitalization will change our industry. We are looking to adapt and seek opportunities in products as services and with a number of potential add-ons to customers and end-users."*
T5	Evidence of lack of awareness of change in the appropriability regimes	S13	There is uncertainty as to how digitalisation will affect BMs for manufacturers	F39	Supplier and Customer Relationships	Q39	*"One way to look at it is that further connectivity with our suppliers and customers will enhance our relationships. The other is that the customers could by-pass us completely and go straight to the suppliers themselves. This is not a new proactive in automotive manufacturing but, digitalisation could increase it."*
T5	Evidence of lack of awareness of change in the appropriability regimes	S14	Manufacturing businesses typically use a very narrow definition of IP as a protection mechanism, but not as a source of revenue	F40	Awareness of intangible asset benefits	Q40	*"We only use patents to protect our inventions, so that if a competitor try to imitate our products we will go after them and make sure we stop it. The thing I am not sure of is whether we can identify people using or imitating our product."*
T5	Evidence of lack of awareness of change in the appropriability regimes	S14	Manufacturing businesses typically use a very narrow definition of IP as a protection mechanism, but not as a source of revenue	F41	Intellectual Property Revenue	Q41	*"We have patents and trademarks but we never made any money with it. I think that should be more like other businesses who license some of their IP to generate revenue."*
T5	Evidence of lack of awareness of change in the appropriability regimes	S14	Manufacturing businesses typically use a very narrow definition of IP as a protection mechanism, but not as a source of revenue	F42	Intellectual Property other benefits	Q42	*"There are businesses out there using IP as a currency in kind to enter into collaborations and even joint ventures, but most of the tier 1 manufacturers we work with in the UK are missing this opportunity."*
T5	Evidence of lack of awareness of change in the appropriability regimes	S15	There is no evidence of manufactures adapting their IP strategies due to digitalisation	F43	No need for an Intellectual Property Strategy	Q43	*"We don't have an Intellectual Property strategy as such, it is typically the business strategy that guides everything else, so if a particular business generates some IP we will try to protect it."*
T5	Evidence of lack of awareness of change in the appropriability regimes	S15	There is no evidence of manufactures adapting their IP strategies due to digitalisation	F44	Follow the market pull	Q44	*"I don't think we will be adapting our strategies, the law is not changing, so in a way it will be the same rules. As always we will strive to comply with the OEM requirements and terms and conditions."*
T5	Evidence of lack of awareness of change in the appropriability regimes	S15	There is no evidence of manufactures adapting their IP strategies due to digitalisation	F45	Impact of digitalisation	Q45	*" ...there are scenarios where we can see companies entering our industry without having any knowledge of our product or processes, but just utilising our product and process data and machine learning. In the same way customers will be able to reverse engineer our costs and squeeze our margins even further."*

TABLE 18 - THEME 5 AND RELATED CODES WITH SINGLE EXAMPLE QUOTES FROM INTERVIEWEES

5.3. Case Study Analysis

As discussed in Chapter 2, one of the most relevant theories in IP strategies for this research is the theory of appropriability. In order to analyse the case studies and summarise the findings, with an emphasis on identifying the impact on the manufacturer's BMs and IPSs, the researcher has selected the theory of appropriability to aggregate the above insights from the in-depth interview analysis with the contractual analysis.

This section will explore three key elements of data analysis. First, the Appropriability Regime framework; secondly, how it was utilised to consolidate and analyse the relevant data for each case study; and finally, the summarised results of the data analysis in the context of each case study.

5.3.1 The Appropriability Regime Framework

The term appropriability, introduced in the IPS literature review in Chapter 2, is used to characterise the extent to which the manufacturer innovating is able to obtain a return equal to the value created by that innovation. Expanding this characterisation, the researcher focused on the circumstances which enable the value generated by technological innovation to be captured.

Furthermore, the term 'appropriability regime' will be used in this context to characterise the business's ability to capture the value generated by an innovation in the context of the automotive manufacturing industry in the UK as documented through this research's case studies.

As also explored in Chapter 2, there is currently a gap in the IPS literature regarding the lack of a framework or tool that can be applied to evaluate a particular appropriability regime, accounting for the various businesses positioned within a given value chain. Such a tool could be utilised in order to identify and address the challenges and opportunities such as those faced by the automotive manufacturers embarking on the I4.0 journey.

With this gap in mind, the researcher has built upon the current theory of appropriability in order to develop a bespoke method called the Manufacturing Appropriability Regime Construct (MARC) in order to consolidate the data collected and provide an assessment of the changes to the manufacturers involved in the case studies.

The current theory on appropriability regimes is composed of two key parts: firstly, the nature of knowledge in the particular innovation; secondly, the strength of the legal protection of intellectual assets. Appropriability regimes are manifested as a function of both the ease of replication and the efficacy of intellectual property rights as a barrier to imitation.

The Appropriability Regime framework provides a perspective on the business-relative position regarding the prospects of its innovations being quickly replicated by the competition. The framework has two main divisions. The first of these is inherent replicability and the second is intellectual property rights. Each of these two broad divisions has two subcategories.

On the horizontal axis, the first subcategory, inherent applicability, is divided into easy or hard, referring to the level of difficulty involved in imitating the innovative product or service. On the vertical axis, the second subcategory, intellectual property rights, is divided into loose or tight intangible asset protection, referring to the level of IP protection available in the context of a particular product or service.

These categories and subcategories create a four-box grid with the fields: weak, moderate, moderate and strong. The following figure demonstrates the four-box framework.

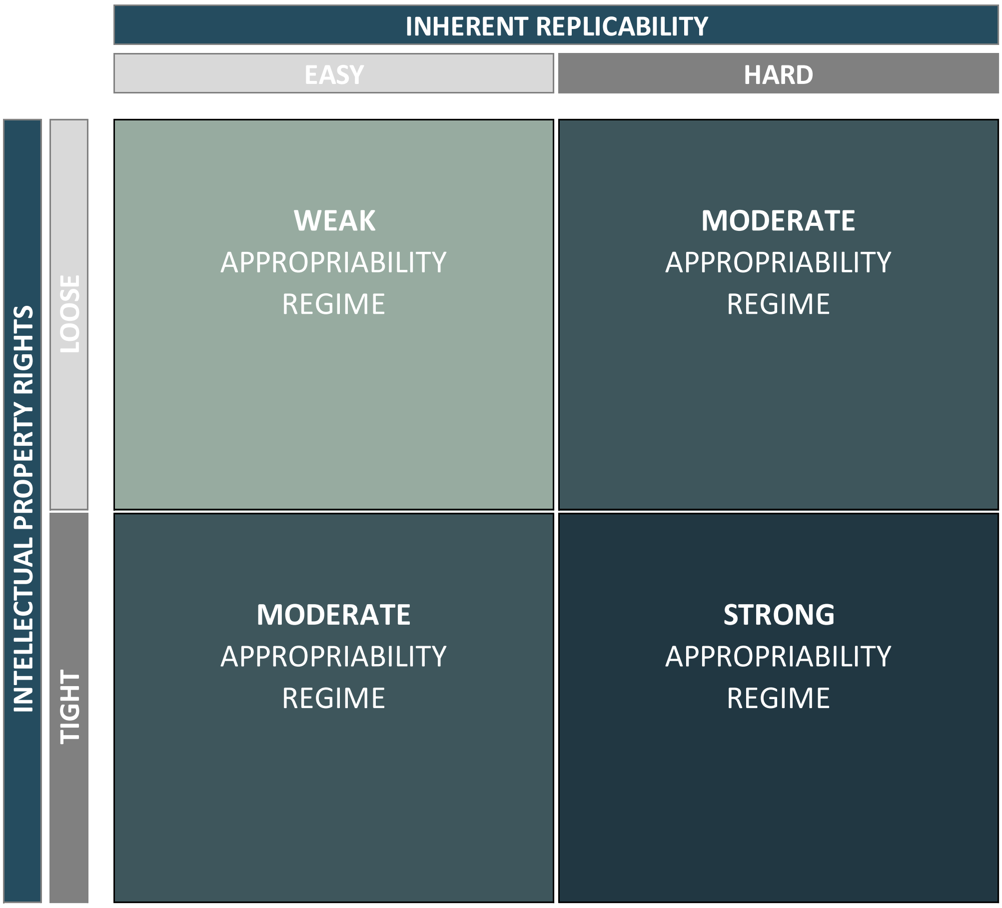

FIGURE 15 - CURRENT THEORY OF APPROPRIABILITY AS REPRESENTED BY THE RESEARCHER

The four quadrants indicate whether the innovator's position is weak, moderate or strong in regard to capturing value from innovation. Each of the fields will be briefly discussed in the following sections in order to explore the analysis of each actor in each of the case studies.

Innovations generated by businesses located in the weak field are easy to imitate, and the intellectual property rights available to protect the innovations are loose. Typically, if the businesses located in this field do nothing to improve the IP protection for their innovations or develop disruptive innovation, they will fail to appropriate value from innovation.

Businesses that continue to focus only on the launch of new products, services or processes with small and incremental adjustments to the existing products or processes typically stay in this weak field and become a producer of standard or commoditised products or services in a homogeneous market.

On the other hand, businesses positioned in the moderate field in the top right-hand corner have a product or process that is hard to replicate; however, their intellectual property rights are loose. Businesses in this field have inherent organisational core competencies which are not protected by law but are difficult to replicate. It is generally more difficult to copy organisational processes and positions from other businesses, as copying and knowledge transfer are difficult between businesses with different competencies and systems.

Businesses in the second moderate field in the bottom left-hand corner have easy-to-replicate products or processes, but their intellectual property rights are tight. Businesses in this field are normally in industries where patents are very strong and protected by law. Copyright and trademarks are very strong because they are important for the customers.

Finally, businesses located in the strong field have hard-to-replicate products or processes and their intellectual property rights are tight, so it is not only difficult to replicate their products or services, it is typically also illegal.

Businesses in this field are normally very innovative; they make use of both incremental and radical innovation. Theoretically, all companies should strive to get to the strongest possible position given their business models and markets. If they are in a strong position, they should strive to maintain the position.

After introducing the theory of appropriability regimes, attention will now turn to the introduction and application of the MARC Model.

5.3.2 The Data Analysis Method – The MARC Model

In order to plot each of the businesses involved in each of the case studies, and to address the theoretical gap regarding a tool or method to evaluate the impact of I4.0 and the horizontal integration of the automotive manufacturing value chains, the researcher has created an evaluation model which looks at identifying and evaluating appropriability indicators for the two axes of the Appropriability Regime framework.

In order to do this, the researcher reviewed the data collected and the literature review with the focus of finding indicators of strong or weak intellectual property rights and indicators of easy- or hard-to-replicate innovations. As a result of this review, the researcher has combined the most prominent building blocks emanating from the literature (Hurmelinna-Laukkanen and Puumalainen 2007) and selected the following appropriability indicators which when combined will provide a perspective on the strength of the Intellectual Property Rights and the Inherent Replicability for each business in the context of case studies which will be explored.

For the Intellectual Property Rights category, the three selected indicators are:

1 – The Practical Means of Protection

This indicator appeared as one of the appropriability regime building blocks in Chapter 2. However, in the context of this evaluation it was consolidated under the Intellectual Property Rights category and designed to assess the practical steps taken to implement practical means of protection for innovation. As part of scoring this indicator the researcher evaluated policies, procedures and cultural aspects of the businesses involved in each case study. These included for example, whether the business have a clear IP policy defining what IP is important for the business and also whether the employees know of, and are trained regularly to execute the procedures under such a policy.

2 – The Contractual Position

Contracts also appeared in the literature as a consideration under multiple appropriability building blocks as discussed in Chapter 2. However, The Contractual Position was designed as one of the critical indicators of the strength of Intellectual Property Rights and placed at a more important level in the evaluation of the appropriability regime. Such increase in importance was due to the fact that during the data collection the researcher was made aware of how contracts between the businesses in each of the case studies made data, information and even registered IP such as patents impossible to appropriate. This was the case particularly with contracts for the supply of products or services with clauses requiring the transfer of all current and future data and IP on the product to one of the contracting parties.

3 – The Intellectual Property Rights Protection

This indicator was designed to assess the actual protection mechanisms utilised by a particular business in the context of the innovation to be evaluated. As part of this assessment the researcher explored the traditional forms of registered IP such as patents and trademarks, as well as, the unregistered form of IP such as trade secrets and copyright protection.

On the other side, for the Inherent Replicability category, the three selected indicators are:

1 – The Nature of Knowledge

This indicator was designed to evaluate the nature of knowledge in the context of a particular innovation. It focuses on the extent to which the knowledge is explicit or tacit and also how consolidate or codified the knowledge is within a value chain. This is a critical indicator in the context of digitalisation which normally codifies as much knowledge as possible in the process, product or business subject to the digitalisation.

2 – The Readiness Level of the Technology

Technology and Manufacturing Readiness Levels (TRL and MRL) are very well known in the disciplines of engineering as a method to indicate how well developed a particular technology is in terms of product or process maturity. The TRL and MRL levels scale starts at Level 1 where basic scientific research is performed to observe and document the concepts of a particular technology and finish at Level 10 where the technology is applied at scale in multiple sectors. The TRL and MRL levels are used in the context of appropriability regimes as an indicator of potential replicability, the higher the TRL and MRL the more widespread the technology is which results in increased chances of imitation by competitors.

3 – The Competency Levels Required

This last indicator was designed to evaluate the levels of skills and competency required to replicate a particular innovation. For example, if the innovation involves common competencies which are widespread across the manufacturing value chain, it is likely that competitors will have a higher potential to imitate. On the other hand, if the competencies required are new and/or scarce it is less likely that competitors will be able to easily replicate the innovation.

All of the above indicators were designed with a 1-10 scale for the evaluation of each business in each of the case studies (where 1 represents low – 10 represents high). Furthermore, the researcher has also introduced a scale of 1–10 for the assessment of the strength of the intellectual property rights on the Y axis which combines the three indicators for the IP strength mentioned above and also a 1-10 scale for the difficulty level for inherent replicability on the X axis as shown in the MARC Model below.

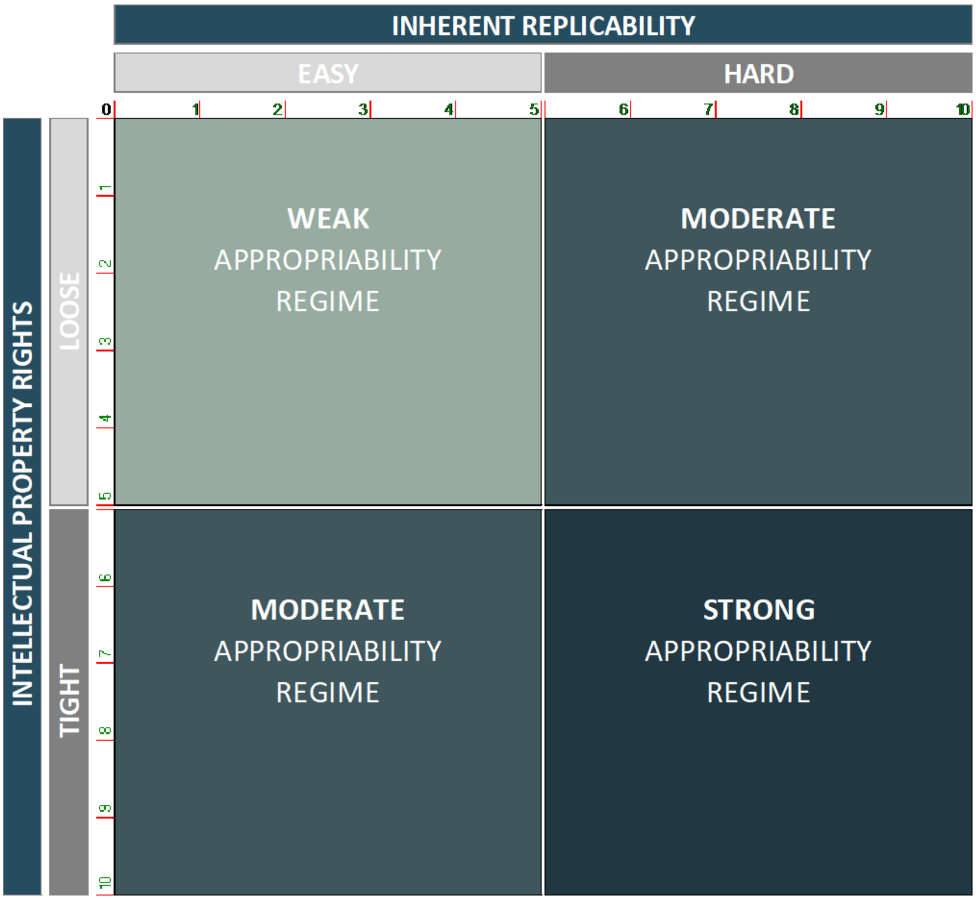

FIGURE 16 - MARC MODEL

In this scale, the number 0 represents the weakest position and the number 10 represents the strongest position in the context of a particular case study.

With the scales in place for each axis, the researcher has turned the focus to the representation of each individual business for each of the case studies. This process began with an evaluation of each individual business in regard to each indicator on a scale of 1–10 in the context of each case study, as shown in table 19 below.

		INTELLECTUAL PROPERTY RIGHTS			INHERENT REPLICABILITY		
		Practical Means	Contractual Position	IPR Protection	Nature of Knowledge	Technology	Competencies
TIER 1	Base line	7	6	5	8	6	7
	Case 1	6	6	6	7	8	5
	Case 2	5	6	5	6	7	3
	Case 3	5	5	5	3	5	5
OEM	Base line	8	8	9	8	6	7
	Case 1	9	9	9	8	8	7
	Case 2	9	9	9	7	8	9
	Case 3	9	10	10	9	8	8
Tech. Partner	Base line	9	9	9	9	8	8
	Case 1	8	9	8	8	9	8
	Case 2	9	9	10	6	8	7
	Case 3	9	8	9	5	7	8
University	Base line	10	10	10	8	7	8
	Case 1	10	10	9	7	7	6
	Case 2	10	10	9	6	6	7
	Case 3	8	10	9	6	5	7

TABLE 19 - INITIAL CASE STUDY INDICATORS

The left axis shows each of the participants in each of the case studies as introduced in Chapter 4. On the other axis across the top, the table shows the appropriability regimes categories and the three indicators for each of the categories.

The researcher has used the data collected through the interviews and the contract analysis which was codified in NVivo in order to give a score between 1 and 10 for each of the indicators in the context of each case study. These scores are located at the intersection between the relevant participant case study and the indicator heading.

In the next step in the MARC analysis, the researcher developed a weighting system designed in order to account for the value of each of the appropriability indicators in the context of each individual business model and value proposition. This weighting system is critical in order to effectively analyse the appropriability regime of a particular business as for example the value of a patent for a manufacturer which is required to transfer such patent to a customer through the contractual agreement for the supply of a product with no value generated through such a patent, may render very strong IP protection through patents for example irrelevant in the context of value appropriation.

This is the case of manufacturers operating a make to print business model in highly competitive value chains such as the automotive manufacturing in the UK where value is only generated through the sales of commoditised products. To address these cases, the researcher has applied a weighting system which scores the particular business model between 1–5 (1 meaning the indicator is not important to the value proposition and 5 meaning the indicator is very important to the value proposition of the business in relation to the particular case study).

Once again, the researcher used the interview information regarding each of the participants' business models and each product, process and manufacturing technology, as well as the contractual information regarding each case study, in order to allocate a weighting to each indicator for each business in each of the case studies as demonstrated in the grey columns of table 20 below.

		INTELLECTUAL PROPERTY RIGHTS						INHERENT REPLICABILITY					
		Practical Means	Weight	Contractual Position	Weight	IPR Protection	Weight	Nature of Knowledge	Weight	Technology	Weight	Competencies	Weight
TIER 1	Base line	7	4	6	4	5	4	8	4	6	4	7	4
	Case 1	6	3	6	4	6	4	7	3	8	4	5	3
	Case 2	5	5	6	2	5	4	6	3	7	4	3	3
	Case 3	5	5	5	2	5	4	3	4	5	3	5	3
OEM	Base line	8	4	8	4	9	4	8	4	6	4	7	4
	Case 1	9	4	9	4	9	4	8	4	8	4	7	4
	Case 2	9	5	9	5	9	4	7	4	8	4	9	4
	Case 3	9	5	10	5	10	4	9	4	8	4	8	4
Tech. Partner	Base line	9	4	9	5	9	5	9	4	8	5	8	4
	Case 1	8	5	9	5	8	5	8	3	9	5	8	3
	Case 2	9	5	9	5	10	5	6	4	8	5	7	3
	Case 3	9	4	8	5	9	5	5	4	7	5	8	3
University	Base line	10	5	10	5	10	5	8	4	7	3	8	5
	Case 1	10	5	10	5	9	5	7	4	7	3	6	5
	Case 2	10	5	10	5	9	5	6	4	6	3	7	5
	Case 3	8	5	10	5	9	5	6	4	5	3	7	5

TABLE 20 - INITIAL CASE STUDY INDICATORS AND WEIGHTS

Finally, the researcher has created a formula to multiply the indicators by the individual weighting scores, to add the results of each indicator within a category and to divide the result by the number of inputs in order to arrive at the weighted score as demonstrated in the calculation below.

$$((xa \times ya) + (xb \times yb) + (xc \times yc)) / Xn = X$$

$$((7 \times 4) + (6 \times 4) + (5 \times 4)) / 6 = 12$$

In the calculation, (xa) represents the indicator for a participant in a case study. (xa) is then multiplied by (ya) which represents the weight of that indicator for a participant in a case study. The sum of the indicators multiplied by the weights is divided by (Xn) which represents the number of inputs in the calculation.

The resulting score was then normalised to the MARC framework scale utilising the following calculation:

$$a + (x - A) \times (b - a) / (B - A)$$

$$0 + (12 - 0.05) \times (10 - 0) / (25 - 0.05) = 4.7$$

In the calculation, (a) represents the lowest value in the MARC scale, (b) represents the highest value in the scale, (A) represents the lowest possible weighted score and (B) represents the highest weighted score. Finally, (x) represents the value to be normalised.

The following table demonstrates the results of the data analysis.

INTELLECTUAL PROPERTY RIGHTS

		Practical Means	Weight	Weighted Scores	Contractual Position	Weight	Weighted Scores	IPR Protection	Weight	Weighted Scores	Total Weighted Score	Normalised Score
TIER 1	Base line	7	4	28	6	4	24	5	4	20	12.0	4.7
	Case 1	6	3	18	6	4	24	6	4	24	11.0	4.3
	Case 2	5	5	25	6	2	12	5	4	20	9.5	3.7
	Case 3	5	5	25	5	2	10	5	4	20	9.2	3.5
OEM	Base line	8	4	32	8	4	32	9	4	36	16.7	6.6
	Case 1	9	4	36	9	4	36	9	4	36	18.0	7.1
	Case 2	9	5	45	9	5	45	9	4	36	21.0	8.4
	Case 3	9	5	45	10	5	50	10	4	40	22.5	9.0
Tech. Partner	Base line	9	4	36	9	5	45	9	5	45	21.0	8.4
	Case 1	8	5	40	9	5	45	8	5	40	20.8	8.3
	Case 2	9	5	45	9	5	45	10	5	50	23.3	9.3
	Case 3	9	4	36	8	5	40	9	5	45	20.2	8.0
University	Base line	10	5	50	10	5	50	10	5	50	25.0	10.0
	Case 1	10	5	50	10	5	50	9	5	45	24.2	9.7
	Case 2	10	5	50	10	5	50	9	5	45	24.2	9.7
	Case 3	8	5	40	10	5	50	9	5	45	22.5	9.0

INHERENT REPLICABILITY

		Nature of Knowledge	Weight	Weighted Scores	Technology	Weight	Weighted Scores	Competencies	Weight	Weighted Scores	Total Weighted Score	Normalised Score
TIER 1	Base line	8	4	32	6	4	24	7	4	28	14.0	5.5
	Case 1	7	3	21	8	4	32	5	3	15	11.3	4.4
	Case 2	6	3	18	7	4	28	3	3	9	9.2	3.5
	Case 3	3	4	12	5	3	15	5	3	15	7.0	2.7
OEM	Base line	8	4	32	6	4	24	7	4	28	14.0	5.5
	Case 1	8	4	32	8	4	32	7	4	28	15.3	6.1
	Case 2	7	4	28	8	4	32	9	4	36	16.0	6.3
	Case 3	9	4	36	8	4	32	8	4	32	16.7	6.6
Tech. Partner	Base line	9	4	36	8	5	40	8	4	32	18.0	7.1
	Case 1	8	3	24	9	5	45	8	3	24	15.5	6.1
	Case 2	6	4	24	8	5	40	7	3	21	14.2	5.6
	Case 3	5	4	20	7	5	35	8	3	24	13.2	5.2
University	Base line	8	4	32	7	3	21	8	5	40	15.5	6.1
	Case 1	7	4	28	7	3	21	6	5	30	13.2	5.2
	Case 2	6	4	24	6	3	18	7	5	35	12.8	5.0
	Case 3	6	4	24	5	3	15	7	5	35	12.3	4.8

TABLE 21 - INITIAL CASE STUDY INDICATORS WITH WEIGHTED AND NORMALISED SCORES

In order to validate the scores and weights, once the calculation was completed, the researcher approached two interviewees from each of the businesses involved in the case studies and reviewed the scores and weights.

This process followed a very simple protocol whereby the researcher presented the Marc Model and the scales and weights and asked the interviewees to self-assess their positions. Once the interviewees independently evaluated their positions, the researcher presented the independent evaluation conducted in advance, discussed the differences and reached a conclusion as to whether the scores needed to be adjusted.

The following table shows, from left to right, the researcher's scores, the interviewee's scores and the differences for both the intellectual property rights scores (represented in the columns labelled IPR) and inherent replicability scores (represented in the columns labelled IH).

		Researcher Score		Self Score		Difference	
		IPR	IH	IPR	IH	IPR	IH
TIER 1	Base line	4	5	4.7	5.5	-0.7	-0.5
	Case 1	4	4	4.3	4.4	-0.3	-0.4
	Case 2	3	3	3.7	3.5	-0.7	-0.5
	Case 3	3	2	3.5	2.7	-0.5	-0.7
OEM	Base line	6	6	6.6	5.5	-0.6	0.5
	Case 1	7	6	7.1	6.1	-0.1	-0.1
	Case 2	8	6	8.4	6.3	-0.4	-0.3
	Case 3	9	7	9.0	6.6	0.0	0.4
Tech. Partner	Base line	9	7	8.4	7.1	0.6	-0.1
	Case 1	9	6	8.3	6.1	0.7	-0.1
	Case 2	9	5	9.3	5.6	-0.3	-0.6
	Case 3	8	5	8.0	5.2	0.0	-0.2
University	Base line	10	6	10.0	6.1	0.0	-0.1
	Case 1	10	5	9.7	5.2	0.3	-0.2
	Case 2	10	4	9.7	5.0	0.3	-1.0
	Case 3	10	4	9.0	4.8	1.0	-0.8

TABLE 22 - RESEARCHER AND SELF-SCORES (INTERVIEWEES) COMPARISON

The results of the data analysis were then plotted onto the MARC Model utilising the colours to represent a particular case study and shapes to represent a particular business within a case study, as demonstrated in the following key figure.

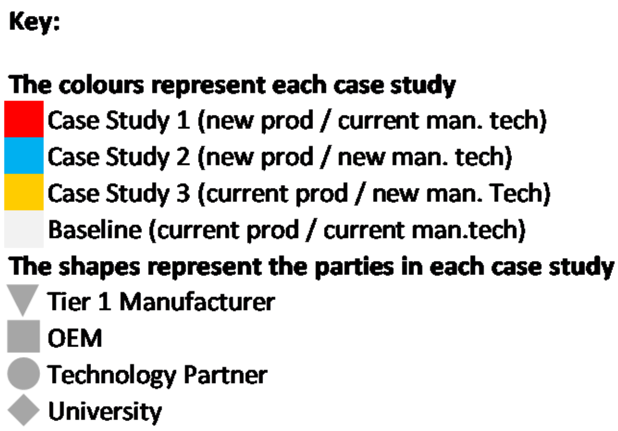

FIGURE 17 - MARC MODEL CASE STUDY KEY

The next sections will explore the analysis results for each case study utilising the MARC Model.

5.3.3 The MARC Analysis – Baseline

In order to demonstrate the difference between the current state of appropriability in the automotive manufacturing value chain, the researcher created a baseline case study which will be used as a comparator for the other three case studies which are the focus of this research.

The baseline case study demonstrates the relationships in regard to a current product being manufactured utilising current manufacturing technologies. It is focused on a product launch project, followed by a customer–supplier relationship in the manufacturing value chain with the objective of producing a current product utilising current facilities and manufacturing technology. A summary of the case study details provided in section 4.3.1 is shown in the following figure.

Case Study Name: Baseline B

Nature of Collaboration Relationship:
Original Equipment Manufacturer (OEM) funded collaboration project to launch existing product into existing factory.

Project Participants:
OEM
Tier 1 Manufacturer
Technology Provider
Tier 2 Manufacturer
Research Institution

Project Length:
12 months

Nature of Commercial Relationship:
Tier 1 commercial contract to manufacture parts for the OEM.

Tier 2 commercial contract to manufacture component for the Tier 1.

Length of Contract:
Tier 1 to OEM = 5 years
Tier 2 to Tier 1 = 5 years

Other information:
Pre-existing agreement governing the IP ownership between OEM and Tier 1.

Data Collection Sources:

Collaboration Agreement	Commercial Agreement
Non-disclosure Agreements	
Employment Contracts	
In-depth Interviews	

FIGURE 18 - CASE STUDY SUMMARY - BASELINE

In addition to the case study summary, the following figure, which was introduced as part of the case study selection discussed in Section 4.2, is also used to inform the reader and highlight the position of the baseline case study in relation to the other three case studies.

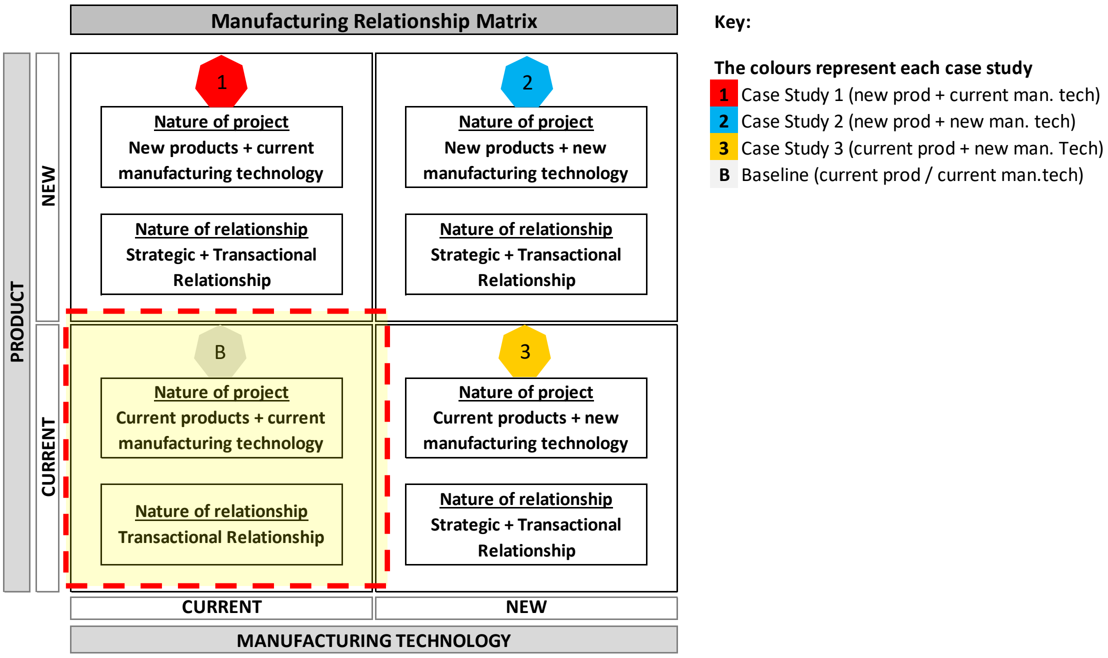

FIGURE 19 - MANUFACTURING RELATIONSHIP MATRIX - BASELINE

The following figure demonstrates the position of each business in the baseline case as a result of the MARC Model analysis.

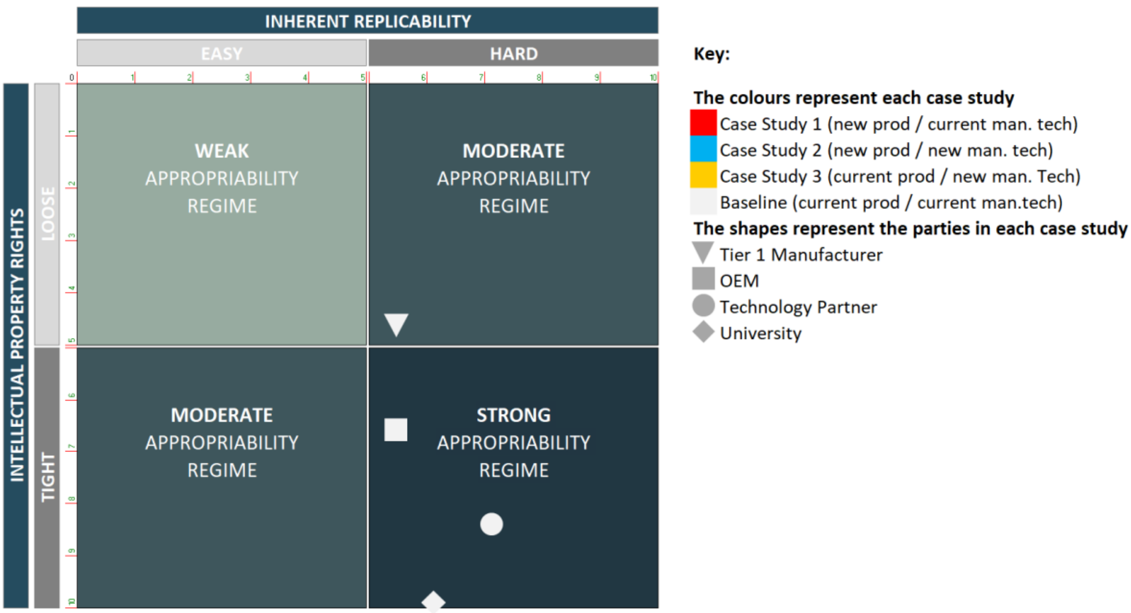

FIGURE 20 - MARC MODEL – BASELINE CASE STUDY

The above model demonstrates that the Tier 1 manufacturer is in the moderate quadrant, with a medium level of IPR protection at 4.7 and also a medium level of inherent replicability scoring 5.5.

The OEM in this baseline case study is located at the strong quadrant scoring 6.6 for IPR and the same inherent replicability score as the Tier 1 manufacturer at 5.5.

The technology partner is also positioned at the strong quadrant, albeit with a stronger score for both areas, IPR at 8.4 and inherent replicability at 7.1.

Finally, the university partner, scoring the highest possible score of IPR, is also positioned at the strong quadrant with scores of 10 for IPR and 6.1 for inherent replicability.

After setting the baseline case study, attention will turn to exploring each of the three main case studies and their respective positions in the MARC Model.

5.3.4 MARC Analysis – Case Study 1

The MARC Model analysis of Case Study 1 demonstrates the state of appropriability in the automotive manufacturing value chain (in red) in comparison to the baseline (in grey).

Case Study 1 provides a scenario which explores the relationships in a collaboration project with the objective of developing a new product utilising digital technologies associated with I4.0. This project is followed by a customer–supplier relationship in the automotive value chain with the objective of manufacturing a new product with current manufacturing technologies. A summary of the case study details provided in section 4.3.2 is shown in the following figure.

Case Study Name: Case Study 1

Collaboration Phase	Commercial Contract Phase
Nature of Collaboration Relationship: Collaborative project to develop new light weighted automotive product to be manufactured in existing facilities. **Project Participants:** OEM Tier 1 Manufacturer Technology Provider Tier 2 Manufacturer Research Institution **Project Length:** 24 months	**Nature of Commercial Relationship:** Tier 1 commercial contract to manufacture parts for the OEM. Tier 2 commercial contract to manufacture component for the Tier 1. **Length of Contract:** Tier 1 to OEM = 5 years Tier 2 to Tier 1 = 5 years **Other information:** Use of digital systems for product lifecycle management across value chain.

Data Collection Sources:

- Collaboration Agreement
- Commercial Agreement
- Non-disclosure Agreements
- Employment Contracts
- In-depth Interviews

FIGURE 21 - CASE STUDY SUMMARY - CASE STUDY 1

In addition to the case study summary, the following figure, which was introduced as part of the case study selection discussed in Section 4.2, is used to highlight the position of Case Study 1 in the context of the other case studies in the manufacturing relationship matrix.

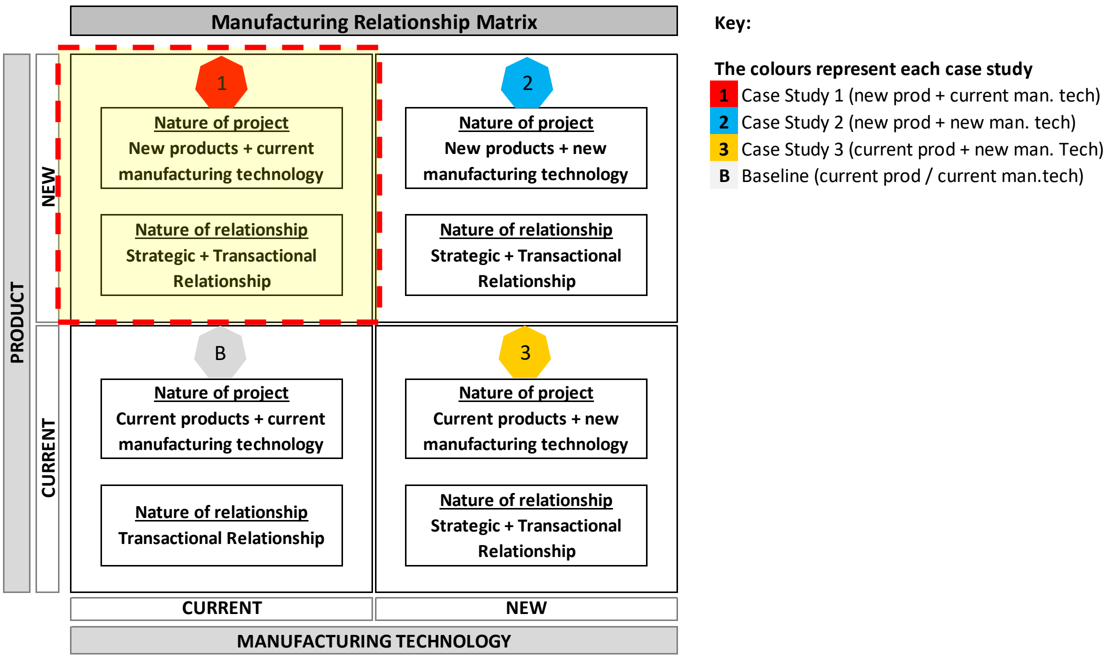

FIGURE 22 - MANUFACTURING RELATIONSHIP MATRIX - CASE STUDY 1

The scores for Case Study 1 demonstrate the movements of each business in the scenario where a new product, designed and developed using I4.0 technologies, is introduced into a Tier 1 manufacturing business utilising current (pre-digitalisation) manufacturing technologies.

The following figure demonstrates the position of each business analysed as part of Case Study 1 in the colour red.

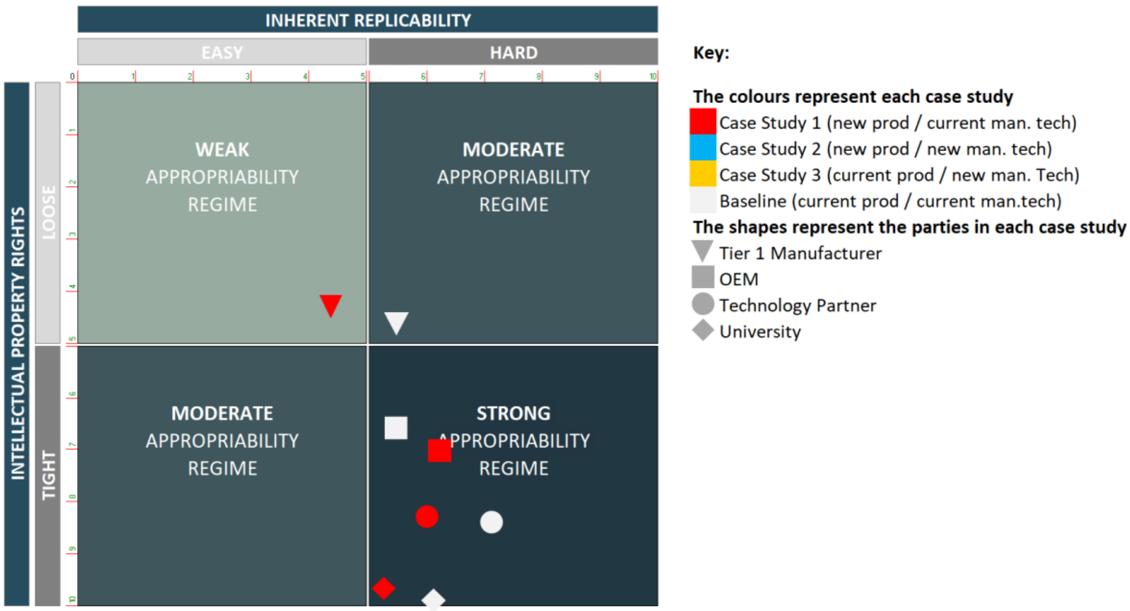

FIGURE 23 - MARC MODEL – CASE STUDY 1

As can be seen in the above Marc Model, the position of the Tier 1 manufacturer is weakened in this particular case, whilst the position of the OEM gains strength. The key influencing factors in this shift are:

I – Changes to the contractual position

These changes include changes to the contractual position which restricted the ability of the Tier 1 manufacturer to appropriate value.

II – Changes to the nature of knowledge

These changes affect the nature of product knowledge, which was codified into the Product Lifecycle Management System (PLM).

The above model demonstrates that the Tier 1 manufacturer is now in the weak quadrant, with a lower level of IPR protection at 4.3, compared to 4.7 in the baseline, with an also lower level of inherent replicability scoring 4.4, compared to 5.5.

The OEM position has improved and remained at the strong quadrant scoring 7.1, compared to 6.6 in the baseline for IPR, and the inherent replicability score has also increased to 6.1, compared to 5.5 in the baseline.

On the other hand, the position of the technology partner in this particular case has suffered. Whilst still positioned at the strong quadrant, the IPR scores slightly decreased to 8.3, compared to 8.4 in the baseline, and inherent replicability has decreased to 6.1 in comparison to 7.1 in the baseline.

Finally, the university partner also remained in the strong quadrant but saw a decrease in both scores with IPR at 9.7, compared to 10 in the baseline, and inherent replicability at 5.2, compared to 6.1 in the baseline.

5.3.5 MARC Analysis – Case Study 2

Case Study 2 provides a scenario which explores the relationships in a collaboration project with the objective of developing a new product and new manufacturing processes utilising digital technologies associated with I4.0. This project is then followed by a customer–supplier relationship in the automotive value chain with the objective of manufacturing a new product with new manufacturing technologies associated with I4.0. A summary of the case study details provided in section 4.3.3 is shown in the following figure.

Case Study Name: Case Study 2

Collaboration Phase	**Commercial Contract Phase**
Nature of Collaboration Relationship: Collaborative project to develop new product for electric vehicles and new manufacturing technologies. **Project Participants:** OEM Tier 1 Manufacturer Technology Provider 2 Tier 2 Manufacturers 3 Research Institutions **Project Length:** 32 months	**Nature of Commercial Relationship:** Tier 1 commercial contract to manufacture parts for the OEM. Tier 2 commercial contract to manufacture component for the Tier 1. **Length of Contract:** Tier 1 to OEM = 18 months Tier 2 to Tier 1 = 18 months **Other information:** Use of digital tools to facilitate concurrent engineering across the value chain.

Data Collection Sources:

- Collaboration Agreement
- Commercial Agreement
- Non-disclosure Agreements
- Employment Contracts
- In-depth Interviews

FIGURE 24 - CASE STUDY SUMMARY - CASE STUDY 2

The following figure, which was introduced as part of the case study selection discussed in Section 4.2, is used to highlight the position of the Case Study 2.

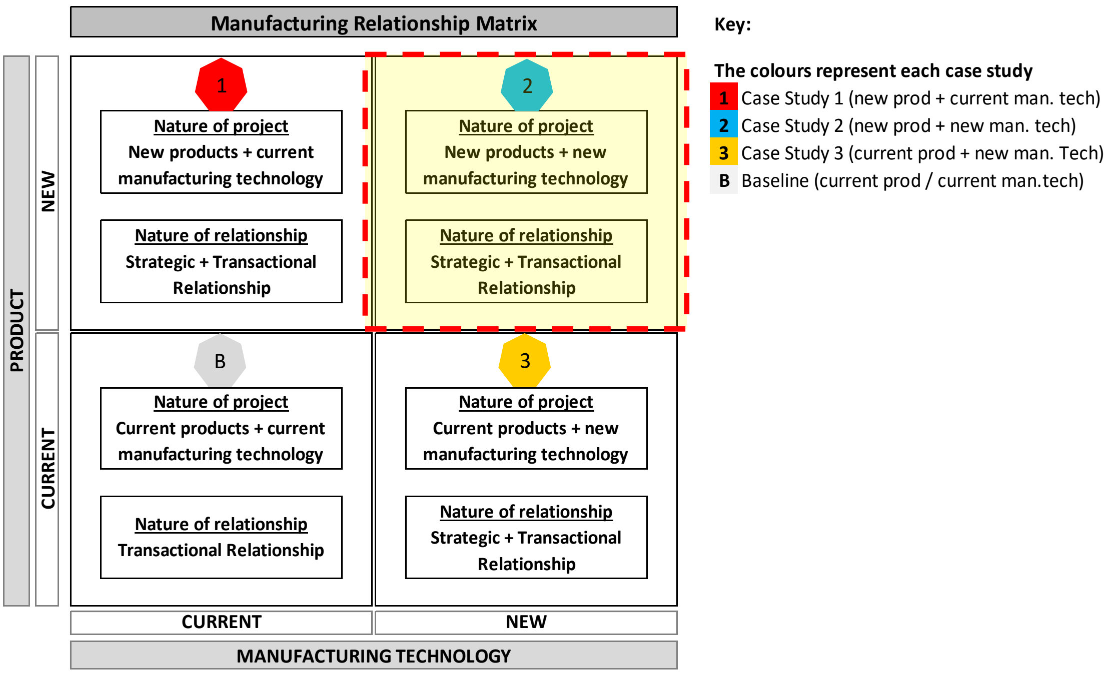

FIGURE 25 - MANUFACTURING RELATIONSHIP MATRIX - CASE STUDY 2

The scores for Case Study 2 demonstrate the movements of each business in the scenario where a new product designed and developed using I4.0 technologies is introduced into a Tier 1 manufacturing business utilising I4.0 digital manufacturing technologies.

The following figure demonstrates the position of each business analysed as part of the case study in the colour blue.

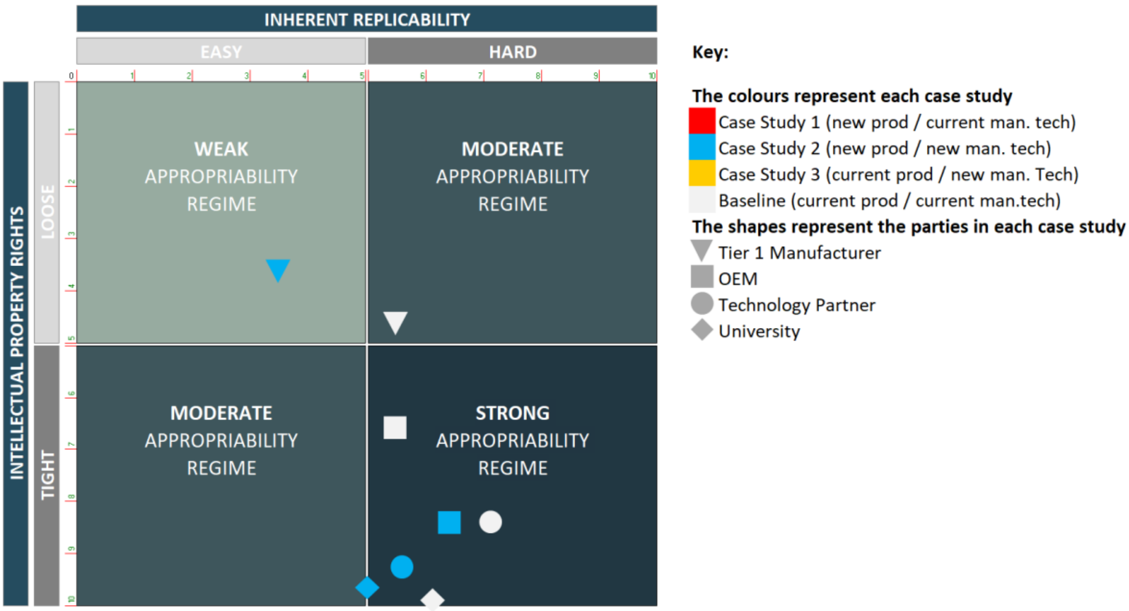

FIGURE 26 - MARC MODEL – CASE STUDY 2

As demonstrated in the MARC Model above, in Case Study 2 the position of the Tier 1 manufacturer is further weakened, whilst the position of the OEM continues to increase in strength. The key influencing factors in this shift are:

I – Changes to the contractual position

New clauses were included in both main agreements controlling the relationship in the collaboration project and the supply chain contracts.

II – Changes to the nature of knowledge

The production knowledge was codified into a single system and a large amount of data from both product and process simulations was shared with all the partners.

III – Changes to the practical means of protection

These changes included uncontrolled operational data exchanged and aggregated in a digital collaboration platform used to simulate product and manufacturing processes in parallel.

IV – Changes in the level of generic competencies

These changes are related to the technical competencies required to manufacture the new product. In this particular case, the new manufacturing method required very generic competencies that can be found in the majority of suppliers in the automotive value chain.

As shown in the MARC Model, the Tier 1 manufacturer is now in the weak quadrant, with a lower level of IPR protection at 3.7, compared to 4.7 in the baseline, with an also lower level of inherent replicability scoring 3.5, compared to 5.5.

The OEM position has improved and remained at the strong quadrant scoring 8.4, compared to 6.6 in the baseline for IPR, and the inherent replicability score has also increased to 6.3, compared to 5.5 in the baseline.

In contrast to Case Study 1, the position for the technology partner has also improved in regard to the IPR score and decreased in regard to the inherent replicability scores. Whilst remaining in the strong quadrant, the IPR increased to 9.3, compared to 8.4 in the baseline, and inherent replicability has decreased to 5.6 in comparison to 7.1 in the baseline.

The university partner's position also remained in the strong quadrant, maintaining the same score as Case Study 1 with IPR at 9.7, which is a decrease compared to 10 in the baseline and also a decrease in inherent replicability at 5.0, compared to 6.1 in the baseline.

5.3.6 MARC Analysis – Case Study 3

Case Study 3 provides a scenario which explores the relationships in a collaboration project with the objective of developing a new manufacturing process utilising digital technologies associated with I4.0. This project is then followed by a customer–supplier relationship in the automotive value chain with the objective of manufacturing a current product with new manufacturing technologies associated with I4.0. A summary of the case study details provided in section 4.3.4 is shown in the following figure.

Case Study Name: Case Study 3

Collaboration Phase	Commercial Contract Phase
Nature of Collaboration Relationship: Collaborative project to develop new processes to improve the production efficiency on current product. **Project Participants:** OEM Tier 1 Manufacturer Technology Provider Tier 2 Manufacturer Research Institution **Project Length:** 24 months	**Nature of Commercial Relationship:** Tier 1 commercial contract to manufacture parts for the OEM. Tier 2 commercial contract to manufacture component for the Tier 1. **Length of Contract:** Tier 1 to OEM = 3 years Tier 2 to Tier 1 = 3 years **Other information:** Pre-existing agreement governing the IP ownership between OEM and Tier 1.

Data Collection Sources:

Collaboration Agreement	Commercial Agreement
Non-disclosure Agreements	
Employment Contracts	
In-depth Interviews	

FIGURE 27 - CASE STUDY SUMMARY - CASE STUDY 3

The following figure, which was introduced as part of the case study selection discussed in Section 4.2, is used to highlight the position of Case Study 3.

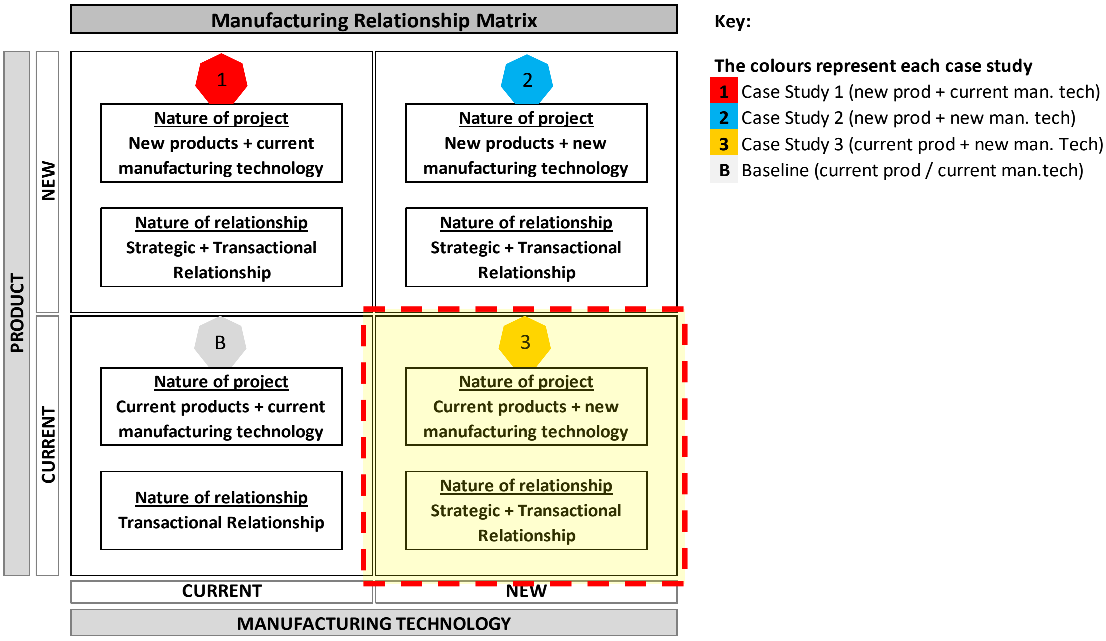

FIGURE 28 - MANUFACTURING RELATIONSHIP MATRIX - CASE STUDY 3

The scores for Case Study 3 demonstrate the movements of each business in the scenario where a current and well-known product being manufactured at scale is moved into a Tier 1 manufacturing business utilising new I4.0-enabled manufacturing technologies (post-digitalisation).

The following figure demonstrates the position of each business analysed as part of the case study in the colour yellow.

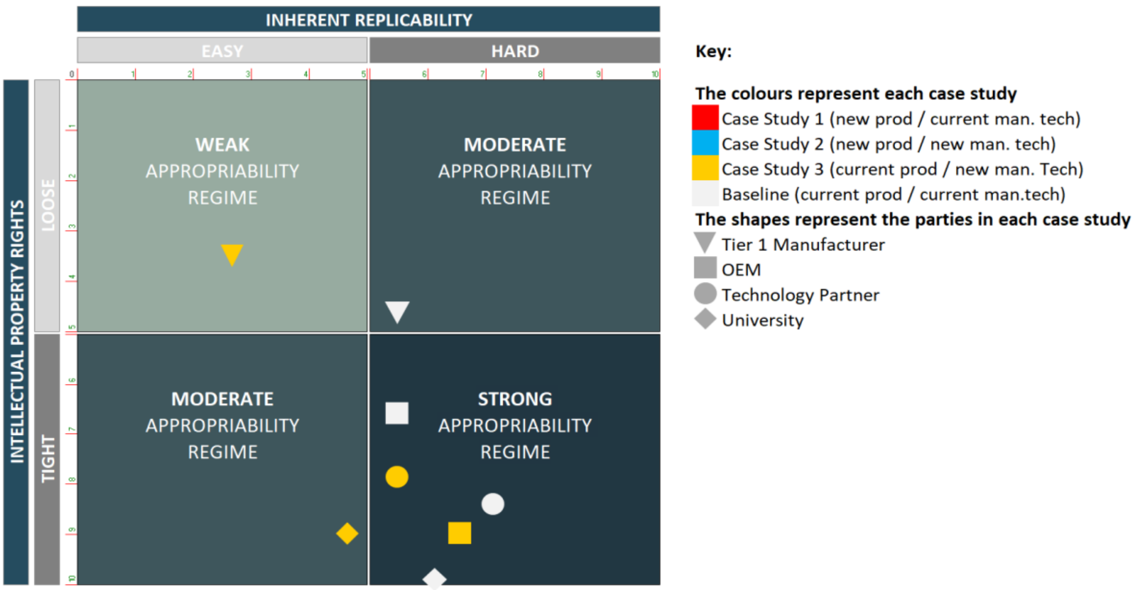

FIGURE 29 - MARC MODEL – CASE STUDY 3

As demonstrated in the MARC Model above, in Case Study 3 the position of the Tier 1 manufacturer is further weakened, whilst the position of the OEM reaches its strongest point. Similarly to Case Study 2, the key influencing factors in this shift in the positions are:

I – Changes to the contractual position

New clauses were included in both main agreements controlling the relationship in the collaboration project and the supply chain contracts. One of these changes imposed significant barriers to the value appropriation on the Tier 1 manufacturer. The most significant of these changes imposed an obligation on the supplier (the Tier 1 manufacturer) to assign all IP in relation to both, product and process to the customer (the OEM).

II – Changes to the nature of knowledge

The production knowledge as well as the new operation data was codified into a single system, and a large amount of data from the Tier 1 manufacturer operations was made available to the OEM and technology partner.

III – Changes to the practical means of protection

These changes included uncontrolled operational data exchanged and aggregated in a digital collaboration platform. It also included the live operational data including investigations and reason codes for process-related issues.

IV – Changes in the level of generic competencies

The product produced in this particular case is very well known to the automotive manufacturers and is commercialised as a commodity. The competencies required to imitate it are widely available in the automotive manufacturing value chain.

The above model demonstrates that the Tier 1 manufacturer is now at the weakest position in comparison to the other case studies, with the lowest scores on both IPR protection at 3.5, compared to 4.7 in the baseline, and the level of inherent replicability scoring 2.7, compared to 5.5.

The OEM position is the strongest across the case studies with an IPR score of 9.0, compared to 6.6 in the baseline and the inherent replicability score of 6.6, compared to 5.5 in the baseline.

Contrary to the OEM, the technology partner position has suffered a detriment on both scores. Whilst still positioned at the strong quadrant, the IPR scores decreased to 8.0, compared to 8.4 in the baseline, and inherent replicability has decreased to 5.2, in comparison to 7.1 in the baseline.

Lastly, the university has also suffered a detriment on its position and a decrease in both scores with IPR at 9.0, compared to 10 in the baseline, and inherent replicability at 4.8, compared to 6.1 in the baseline.

5.4. The MARC Model Analysis Summary

Having explored the analysis of each case study individually and in comparison to the baseline case study, this final section of Chapter 5 will summarise the initial findings into a single MARC Model figure in order to demonstrate the impact on I4.0 on the automotive manufacturing value chain in the context of the three case studies.

5.4.1 The Change of Positioning Across the Case Studies

In this section all businesses participating in the case studies are plotted in a single figure in order to provide a comparison between each of the case studies and the impact and change of position across all case studies.

The following figure demonstrates the position of each of the businesses in the case studies.

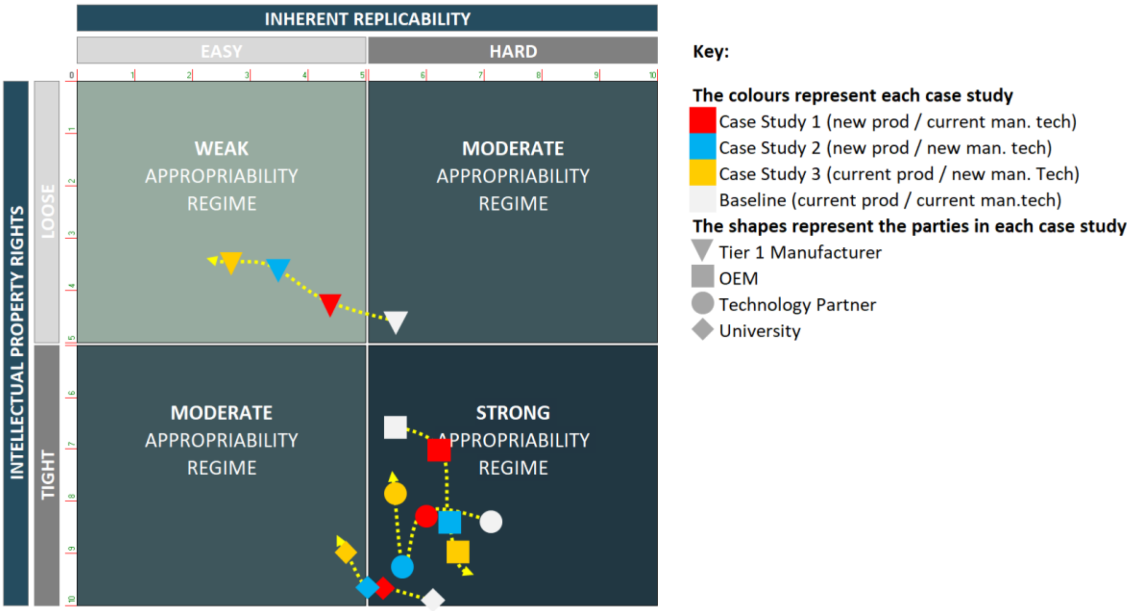

FIGURE 30 - MARC MODEL – COMBINED CASE STUDIES

This combined view of the MARC Model provides a unique view of the transformation in the automotive manufacturing appropriability landscape which results from the introduction of digital technology associated with I4.0 in the context of the case studies subject to this research.

At a glance, the model demonstrates that apart from the OEM who invariably improves its appropriability position in all case studies, all other parties are in a weaker position due to the adoption of digital technologies and the integration of the value chain in these projects. The following paragraphs will provide a summary of each quadrant in the MARC Model and the implications for the businesses in such positions.

The Weak Appropriability Quadrant

As demonstrated in the model above, the Tier 1 manufacturer is typically in the weak quadrant. Businesses in this position are normally mass producers of products without trademark, or standard products in an industry where it is easy to replicate the products. These businesses typically have no property rights on the product or the processes of manufacturing the product.

Manufacturing businesses in this field typically become producers of commoditised or standard products or services which are not protected. This reduces the chances of appropriating value and investment in innovative products or processes.

The first Moderate Appropriability Quadrant (Top Right)

As shown in the model, apart from the Tier 1 manufacturer in the baseline, there are no businesses positioned in the first moderate field. An example of a business that is positioned in this quadrant would be IKEA, the Swedish furniture giant which has a unique distribution and logistics system. Businesses in this quadrant typically also have a very extensive knowledge of their customers and draw on this knowledge continuously; they are in a constant learning process and as a result, even though their IP rights protection is weak, other organisations find it very difficult to imitate their processes.

The second Moderate Appropriability Quadrant (Bottom Left)

As the model demonstrates, the university partners are positioned in the second moderate quadrant in Case Study 2 and Case Study 3. This position is typical of businesses that have strong intellectual property processes and protection through IP rights such as patents and strong trademarks that protect them from imitation by competitors. Nevertheless, their products or technologies are relatively easy to replicate, which appears to be a change in the case of university partners in scenarios such as Case Study 2 and Case Study 3 where vast amounts of information are aggregated and shared across multiple entities.

The Strong Appropriability Quadrant

As is also shown in the above model, the technology partners and the OEMs are typically positioned in the strong quadrant due to very strong intellectual property processes, as well as strong research and development departments. It is also difficult for other companies to copy their ability to develop new products, processes and competency areas.

Additionally, OEMs and technology partners maintain this position by locking collaborators and partner into strong contracts where the ownership of IP in relation to products and processes is typically controlled by them.

5.4.2 The Impact of I4.0 on Appropriability

This section summarises the findings revealed by the MARC Model analysis in regard to the impact on I4.0 on automotive manufacturers in the context of the case studies. These findings and their implications will be discussed in detail in Chapter 6.

In terms of general findings observed by the researcher through the data analysis, the following list provides the key observations.

1. In general, the implementation of I4.0 alters the appropriability regime and leads to stronger positions for OEMs and weaker positions for Tier 1 manufacturers.
2. Apart from the OEMs, as a result of utilising I4.0 technologies in the case studies, all businesses demonstrated a negative shift in inherent replicability.
3. The Tier 1 manufacturer suffered the highest level of detriment to the appropriability regime in the case study where current products were manufactured utilising new I4.0 technologies (Case Study 3), in a value chain with

a high level of similar competencies and knowledge which resulted in innovations easy to replicate.

These general observations are associated with a number of key factors which are likely to influence the appropriability regimes and the IP strategies in the automotive manufacturing value chain in the context of I4.0. These key factors include for example:

a) The formation of highly connected value chains

b) The shift from tacit to codified knowledge

c) The formation of value chains with high intensity of data/information exchange

d) The shift towards the digital engineering and digitalised product life-cycle management across the value chains

e) The use of out-of-date contractual agreements conflicting with the current business strategies

f) The lack of IP strategy or the use of inadequate IP strategies and tools

g) The increasingly blurred industry boundaries where similar competencies can be leveraged to disrupt incumbent manufacturing businesses

These brief observations emanating from the MARC Model provide a different perspective on the data collected though the interviews and the contractual analysis which exposes a unique view of the impact I4.0 adoption at different levels of the value chain across the case studies.

It is argued that this view enables automotive manufacturers to evaluate the impact of I4.0 on their appropriability regimes for different scenarios. This can be used to support manufacturers in considering the new business models emerging from the implementation of I4.0 and the changes that may be required to their IP strategies. Developing an effective IP strategy is of paramount importance for manufactures seeking to secure a strong return on investment in the horizontally integrated value chain.

The MARC model is a unique multidisciplinary tool that addresses the gap in the literature discussed in Chapter 2, as well as a practical gap in regards to a method to support manufacturing businesses in identifying their relative position in terms of value appropriation in their value chain. The multidisciplinary aspects of the model are demonstrated by taking into account the main actors' business models, the particular technologies deployed, and the value appropriation strategies utilised by each actor. This has the potential to improve the manufacturers' decision-making processes and the prospects of value capture.

5.5. Chapter 5 Conclusion

This chapter has explored how the researcher has organised and analysed the data collected through two main approaches, firstly the coding process and secondly the MARC Model.

The chapter has also presented five themes that emerged from the data analysis, namely: I) "Industry 4.0 leads to a shift in the nature of knowledge towards codification"; II) "Evidence of a pre-paradigmatic phase in digital manufacturing"; III) "Evidence of recognition of a shift on tangible/intangible assets as source of competitive advantage"; IV) "Evidence of limited knowledge and application of protection mechanisms for value appropriation"; and lastly V) "Evidence of lack of awareness of change in the appropriability regimes".

Lastly, the chapter also presented the process behind the MARC Model analysis, as well as the high-level findings demonstrating the impact of I4.0 on the case studies' participants. The next chapter will discuss these findings and their consequences for automotive manufacturers, as well as providing answers to the research questions and recommendations to address some of the risks and opportunities emanating from these changes.

6. Chapter 6 - Discussion

6.1. Introduction

This chapter specifically focuses on how the empirical work relates to the initial research questions and the literature review. To this end, the structure in this section is adopted to firstly explore the gaps found in the literature in the context of each research question. Secondly, it aims to discuss the research findings in the context of each gap, and thirdly, it will conclude with a discussion of the contribution to theory and practice provided by the findings. In this manner, each of the research sub-questions and the data analysis themes will be examined before returning to the main research question posed in this study.

The theoretical basis for the analysis was established in Chapter 3. The aim is to explore how manufacturing businesses are affected by I4.0 through the BM lens in order to identify the impact on the manufacturers' IPS.

Table 23 below shows the research questions as explored in Chapter 1.

Research question	What is the impact of horizontal integration on current manufacturing business models and intellectual property strategies and how these can be changed to address risks and opportunities?
Sub-question 1	What is Industry 4.0 and horizontal integration in the context of Industry 4.0?
Sub-question 2	How is horizontal integration likely to impact current manufacturing business models?
Sub-question 3	How is horizontal integration likely to impact manufacturing intellectual property strategies?
Sub-question 4	How can the current intellectual property strategies be adapted in order to address the risks and opportunities regarding value appropriation in the manufacturing value chain?

TABLE 23 - RESEARCH QUESTION AND SUB-QUESTIONS

Furthermore, Table 24 has been created in order to demonstrate the relationship between, from left to right, the gaps emerging from the literature, the research questions and the primary themes emerging from the data analysis.

This table will be used throughout this chapter to reference particular gaps with the acronym (LRT) standing for Literature Review Theme and the data analysis themes represented by the letter (T) followed by the number.

Literature review data Emerging gaps		Research questions		Interview data Emerging themes
There is a gap in the literature regarding an empirical and comprehensive account of I4.0, particularly in respect of the horizontal integration of manufacturing value chains, as well as its implications for manufacturing businesses, their BMs and value appropriation driven by intellectual property strategies.	LGR1	What is the impact of horizontal integration on current manufacturing business models and intellectual property strategies and how these can be changed to address risks and opportunities?	T1	Industry 4.0 leads to a shift in the nature of knowledge towards codification
There is a gap in the business model literature with regard to empirical evidence demonstrating the impact of Industry 4.0 on manufacturers' business models adopting this new paradigm. Such study could provide the basis for a business strategy, business model and IP strategy framework to be deployed in order to support academia and practice to account for the impact of Industry 4.0 on current manufacturing business models in the face of the horizontal integration of businesses within the value chain.	LGR2	**Sub-question 1** What is Industry 4.0 and horizontal integration in the context of Industry 4.0?	T2	Evidence of a pre-paradigmatic phase in digital manufacturing
		Sub-question 2 How is Industry 4.0 going to impact current manufacturing business models?	T3	Evidence of recognition of a shift on tangible/intangible assets as source of competitive advantage
Finally, it is argued that the literature review demonstrates that there is a gap regarding a detailed analysis of the impact of I4.0 horizontal integration on manufacturing businesses, business models and their respective IP strategies, with special attention to differences and similarities of each BM (current and/or new) and the position of the business within the manufacturing value chain and the extent to which the appropriation regime for manufacturers will be impacted. Thus, it is important to understand how IP strategies can be adjusted to protect innovation, and to boost the manufacturer's performance in the I4.0 horizontally integrated value chains.	LGR3	**Sub-question 3** How is Industry 4.0 going to impact current manufacturing intellectual property strategies?	T4	Evidence of limited knowledge and application of protection mechanisms for value appropriation
		Sub-question 4 How can the current intellectual property strategies be adapted in order to address risk and opportunities?	T5	Evidence of lack of awareness of change in the appropriability regimes

TABLE 24 - RESEARCH Q&A CONSOLIDATION

The next few sections of this chapter will discuss the findings resulting from this research which contribute to answering the research question and sub-questions, by exploring first the gap in the literature, followed by the research findings in regard to each question and finally, providing a conclusion to each question.

6.2. The I4.0 and Horizontal Integration

6.2.1 The Theoretical Gap

As discussed in Chapter 2 and shown in the first column on the left of table 24 in the cell reference LRT1, there is a gap in the literature regarding an empirical and comprehensive account of I4.0, particularly in respect of the horizontal integration of manufacturing value chains, the impact and the implications for manufacturing businesses, their BMs and value appropriation driven by Intellectual property strategies.

As demonstrated in both the literature review and empirical data, even though I4.0 has, since its conception, moved up the agenda for universities, companies and governments, the definition provided by the myriad of publications in both academic and practitioner domains has varied massively and still a subject of debate. The interviews have shown a similar level of confusion and uncertainty.

A simple way to explain I4.0 is to use the widespread and well-understood technological concept known as the Internet. The Internet is composed of a global network of interconnected computer servers which can be accessed simultaneously by multiple users via a range of endpoint devices (mobile phones, laptops, tablets, PCs, etc.). These connected users access the Internet and utilise the information contained in those servers.

The I4.0 users (these are people and businesses across the value chains) will be connected in the same way as the Internet users. I4.0 expands the concept of connecting these users in the Internet scenario into a scenario where everyday household products containing embedded sensors and communicating information through local networks and the Internet. Such objects can include mobile phones, wearable devices, washing machines, light bulbs, vehicles, etc. In an industrial setting, these devices include robots, machines, jet engines, etc.

All of these ‘things’ are now ‘smart’ objects which are capable of communicating and exchanging data with the wider network about itself (e.g., what, where, when, temperature, pressure, acceleration, speed, status, etc.), making this network the IOT.

Thus, with a basic understanding of IOT, one can begin to understand the concept of I4.0, which can be characterised as a form of ‘Industrial Internet of Things’ (IIOT) (Leber 2012). This term alludes to the previously discussed IOT concept, but applied in the industrial context, as mentioned above, in the form of connected robots, machines, jet engines, other equipment, etc.

This characterisation is similar to the one made by Kirazli and Hormann (2015, p.864), which provides the following definition for I4.0:

“Industry 4.0 is the systematic development of an intelligent, real-time capable, horizontal and vertical networking of humans, objects and systems.”

Therefore, it is argued by the researcher that based on the literature review and data collection I4.0 can be characterised as the deployment of IIOT within the boundaries of an individual business, also known as ‘vertical integration’, as well as across the value chain, industry or even cross-industry, also known as ‘horizontal integration’ (Kagermann et al. 2015).

Of particular importance to this project is the data generated by humans, objects and systems that will be uploaded at different frequencies depending on the use case and utilised in conjunction with other data sets from other devices and other businesses in the automotive manufacturing value chain connected in the IIOT ecosystem.

To conclude, regarding the theoretical gap, there is a recognition that literature lacks a comprehensive account of I4.0 in respect of the horizontal integration, with some authors pointing out that management research is lagging behind on I4.0 (Brettel et al. 2014; Emmrich et al. 2015; Arnold, Kiel and Voigt 2016).

To this end, the next few paragraphs will discuss the key findings from the data analysis and how they contribute to shed light on this particular gap.

6.2.2 I4.0 Horizontal Integration Empirical Findings

As discussed in Chapter 5, the empirical findings condensed into the core themes show that there is evidence of a pre-paradigmatic phase in digital manufacturing. This is a confirmatory finding that not only is management research lagging behind on the impact of I4.0, but also that in practice the businesses interviewed have a general lack of clarity on the value of digitalisation for manufacturing, as well as uncertainty regarding 'risks and benefits' due to having no real examples to demonstrate horizontal integration in manufacturing.

On the other hand, quite paradoxically, the empirical data also shows that there is an acceptance amongst the interviewed businesses that the manufacturers need to digitalise. The data analysis has also shown evidence of increased codification of knowledge and an increase in collaborations across the manufacturing supply chain, with most of the interviewees recognising that manufacturing businesses are moving towards a knowledge-based economy, where data and information are increasingly viewed as more important than tangible assets such as machines and tools.

These findings contribute to the elucidation of the question posed at the beginning of this section, in as much as it shows clear evidence that Industry 4.0 leads to a shift in the nature of knowledge towards codification. This indicates that knowledge, which can be explicit or tacit, is being transformed. This is important as explicit knowledge required in order to apply technologies must be protected, as it can in most cases quite easily be replicated. As pointed out by Hurmelinna-Laukkanen and Puumalainen (2007), if codified information is key to the value proposition of a business, it should be protected with great care.

The interviews demonstrated that due to the market changes in the automotive manufacturing industry, there is a push for manufacturers to digitalise their businesses, even when there is a level of uncertainty as to the benefits and consequences of doing so. This push for digitalisation results in a transformation of tacit knowledge which is more difficult to acquire and to replicate as this knowledge is typically embedded in processes, capabilities and in an individual's head in the case of some manufacturers interviewed.

Manufacturing digitalisation changes the nature of knowledge, as when digital technologies are introduced to manufacturing businesses it often happens in the form of digital data acquisition methods and/or processors which are deployed to control and monitor processes and machines. A common example of this transformation regarding process digitalisation is the adoption of Product Lifecycle Management software tools, which integrate product design with manufacturing design and simulation. These are also known as the digital twin of the product and of the production.

In terms of machine control and monitoring, sensors are typically installed in processes and machines to measure physical parameters, e.g. the power, vibration, pressure or speed of a particular machine or properties of a material. The indicators collected can be compared to a digital model (digital twin of execution) and inform decisions to increase operational effectiveness and productivity.

The data generated during the design process or the execution can then be gathered in databases for later analysis or analysed in real time (e.g. for software-generated decision-making). For example, these data analyses can help tell managers how products or components are doing and if they need maintenance, how well the products are performing. This codified data can thereby help give technical insight (e.g. data on product usage that might enable improvements in product design and functionality) as well as business insight (e.g. data on product usage that might inspire additional services to be offered).

In more general terms, such data can thus be said to create additional value from a product. Many of the interviewees also explicitly expressed a view of data having value, by stating that e.g. data is an asset, data can be used in negotiations, data can help build better products, data through analysis can reveal secrets to or from competitors, and so on.

6.2.3 Horizontal Integration in Manufacturing

According to the empirical data, Industry 4.0 and horizontal integration results in the consolidation and codification of tacit knowledge, which in the past was undocumented and spread across disperse departments and teams which had limited interaction, shared understanding and trust.

As the interviewees pointed out, the digital tools being deployed to integrate businesses vertically and horizontally to support higher flexibility and control in manufacturing is transforming this paradigm.

This will typically include a number of different stakeholders, ranging from device and sensor manufacturers, software and application companies, as well as infrastructure and data analytics companies. These companies will be involved, not only in the manufacturing process, but also in the process of collecting, transferring, storing and analysing data, which gives rise to challenges to IP in the form of data, knowledge and information protection and ownership.

The researcher argues that based on the data analysis, the deployment of IIOT across value chains and industries, crossing individual business boundaries, will pose particular challenges to IP, especially regarding data and knowledge sharing.

This finding from the empirical data contributes to addressing the gap highlighted in the I4.0 literature (see LTR1 in Table 24 Research Q&A Consolidation) as it provides evidence of the impact of I4.0, particularly in respect of the horizontal integration of the automotive manufacturing value chain and its implications for manufacturing businesses, their BMs and value appropriation driven by intellectual property strategies.

These findings also demonstrate that due to digitalisation of manufacturing, the nature of knowledge in the businesses interviewed is shifting from mostly tacit knowledge, which in the past was limited to acquisition via practical means of experience in the relevant technology in the relevant context, to explicit knowledge, which is codified into the new digital systems and thus can be replicated and reverse-engineered easily in an environment such as a horizontally integrated value chain where multiple partners and collaborators may have access to the data.

This makes it difficult for manufacturers to protect their knowledge and appropriate value from their innovations as the tacit knowledge also works as a form of protection from imitation due to limits on how competitors could acquire and replicate this tacit knowledge.

Finally, another important point regarding the impact on manufacturing businesses is the fact that, as demonstrated by the appropriability regime studies conducted by Hurmelinna-Laukkanen and Puumalainen (2007), in industries where knowledge is highly codified, businesses must rely on different mechanisms to protect innovations and the possible corresponding returns. To this end, see the discussion in section 6.5 below, which addresses the recommended actions regarding protective mechanisms.

Having concluded the discussion on the findings regarding the first sub-question, attention will now turn to the second sub-question.

6.3. I4.0 and Manufacturing BMs

6.3.1 The Theoretical Gap

As discussed in Chapter 2, there is a gap in the business model literature regarding the impact on the manufacturing business models of Industry 4.0 horizontal integration. Furthermore, as it was also argued, based on an analysis of the current elements of the various business model theories, there is no single set of elements capable of accounting for all aspects of horizontal integration necessary to evaluate the impact of interconnected relationships emanating from the adoption of I4.0 in the automotive manufacturing value chain.

The literature recognises that I4.0 will lead to extensive organisational consequences for manufacturing, and that manufacturers will be required to adapt to stay competitive. However, there is a gap in the literature due to the limited empirical, in-depth research on the impact of I4.0 on manufacturers.

The literature also argues that even if a consensus was ever reached in the literature in regard to a BM concept, a single accepted conceptual definition might not be fruitful to practice, nor to academia. Such a conceptual definition would have to be too broad to account for every case and every perspective, in which case it would lead to even more misunderstandings and misapplications (Zott and Amit, 2013).

6.3.2 I4.0 in Manufacturing Empirical Findings

The empirical data collected in this study shows that the digitalisation of manufacturing businesses in the UK automotive industry is still in a pre-paradigmatic phase, as there is a general lack of clarity on the architectural model or topology of I4.0 as well as the form and value of digitalisation for manufacturing businesses as demonstrated by the interviews.

This finding also contributes to addressing the gaps in the I4.0 literature as presented in the section LTR1 (in the above Table 24 Research Q&A Consolidation) as it provides evidence that the impact of I4.0 on the manufacturing BMs and value appropriation is unclear to manufacturers embarking on the I4.0 journey.

The history of the automotive industry provides a great example of the importance of identifying the correct approach to innovation in a pre-paradigmatic stage, as this factor has a critical impact in the future success of the innovator. In the example of auto manufacturers, first manufacturers of steam cars did not succeed and were pushed out of business by the disruption brought by the introduction of the internal combustion engine (ICE) as the automotive paradigm. We are now living through another phase of transformation in the switch between the ICE engines and the allegedly more environmentally friendly vehicles such as electric and hybrid vehicles.

The findings from the empirical data analysis presented in this research contributes to the literature as it shows that the interviewees believe that there are no real examples to demonstrate horizontal integration in manufacturing and there is a lack of real-life examples of both risks and benefits which are supposedly emanating from the digitalisation of manufacturing.

It appears that multiple parallel and sequential prototypes of digital manufacturing are being trialled. Generally, such an approach is simply prohibitively costly when the development costs for digitalising a business and a value chain in an uncoordinated manner and the associated disruption to operations are too high.

The findings of this study also contribute by filling the gap in the businesses model literature as exposed in the literature review (see LTR2 in Table 24 Research Q&A Consolidation). The data analysis demonstrates that manufacturers are unable to evaluate the impact of the collaborative and interconnected value chains emanating from the adoption of I4.0.

It is also argued that due to this lack of clarity, it will be difficult for manufacturers to identify the best way to approach digitalisation. It is likely that those that go first and try to solve the challenges alone risk investing in obsolete systems and configurations that will tie them into flawed investments.

On the other hand, those that figure out a viable approach for the whole value chain and can coordinate the distribution and capture of value are likely to have a significant advantage. As argued by Teece (2006), in pre-paradigmatic stages, those businesses that are closer to the market and have better value chain relationships will have a better chance of developing a design that will form the new paradigm.

This means that in the case of manufacturers, the closer you are to your customers and the more in tune with the manufacturer value chains, the higher the manufacturer's chances are of deriving a long-standing source of competitive advantage from their digitalisation efforts.

This closeness can support manufacturers to sense the required changes and to transform multiple facets of their business models such as customer relationships, key partners, and value proposition. All these facets can be enhanced by different products and services emanating from the data being harvested in horizontally integrated value chains.

This value proposition will be further demonstrated in the next section which looks at the evidence regarding a shift in the sources of competitive advantage amongst the manufacturers interviewed.

As discussed in Chapter 5 as part of the data analysis, numerous interviewees in this study described data as a useful or valuable “thing” which does not necessarily fit into the typical definition of intellectual property or of value for manufacturers. Nonetheless, a number of the interviewees have identified that data and the information and knowledge contained in the data generated within their business is perceived as a source of value and therefore should be protected as an asset.

This finding contributes to the literature on business models and IP strategies as it addresses the gaps regarding the impact of I4.0 implementation on manufacturing business models and their IP strategies for value generation and appropriation (LRT2 and LRT3 Table 24 Research Q&A Consolidation) by demonstrating that there is a shift in the sources of competitive advantage which are increasingly driven by intangible assets, such as data, as will be explained in the following paragraphs.

In the scenario where manufacturers begin to look at data as a sort of intangible asset, multiple important questions need to be answered on a business level. How should the manufacturers create and strategically manage their data? How should these data sets be protected? How can data be valued? Which legal mechanisms should be used to protect data? All of these questions would still be relevant even if data was considered as an IP. The manufacturer’s interpretation and distinction between data as an intangible asset, rather than an IP, thus should have no direct implications.

In the business context, an asset is typically valuable in the sense that it can be owned or controlled and turned into economic value. Labelling data as a sort of intangible asset helps us to understand it more broadly than earlier suggestions such as calling it just data or an information asset (Borek et al. 2013). One important question to pose is, can data be truly controlled and protected in a horizontally integrated environment and can it be held exclusively by a single business working in the context of I4.0 value chains (Granstrand 2018)? Such an approach could incentivise trade in data and thus enable further diffusion of existing data in different applications.

It has been argued by Reitzig (2004); Al-Aali and Teece (2013) that a combination of IP or intangible assets into bundles increases the overall value. As such, manufacturers should seek to incorporate data management under the umbrella of what today is typically called IP management. Potential synergies and complementarities could also be more easily explored if all IP was to be managed together, thus increasing the total value of the intangible assets.

For example, a manufacturer of automotive steel fuel tanks may be able to approach a potential AI software partner with products to analyse and develop intelligence to support its operations, but also with a valuable data set to be used in the processes of pressing and joining in the field data collection. These additional elements might help motivate additional IPR allocation towards the manufacturer in negotiations or create a form of intangible asset-based bargaining chip to use with the AI software partner. It thus seems reasonable to say that data should be managed within the overall IP strategy.

Another important point emanating from the empirical data and addressing the gaps in the literature in IP strategies (LRT3) is the recognition of the need for improving the IP competence across all functions in manufacturing. This competence gap was justified because manufacturers are moving into increasingly complex collaborations where multiple individuals work on the day-to-day delivery of the project and could be the source of new innovations or spillage of innovation to collaborators.

Additionally, manufacturers should also recognise that due to the codification of knowledge and the importance of data for future product and process development, the digitalisation of manufacturing is likely to result in weaker appropriability regimes as shown in the MARC Model analysis in Chapter 5. As a result, a new set of IP strategies for manufacturing businesses, which account for the new sources of competitive advantage, new relationships and new types of intangible assets, is required.

The main approach mentioned by the interviewees regarding the manufacturers' efforts to address this change and the competence gap were: i) providing training and education to current staff; ii) building closer relations and relying to a larger extent on external expertise from existing legal teams or consultants; and finally iii) recruiting people into a key position with a background in an industry where IP was seen as an important element for business growth and value appropriation.

Of these approaches, acquiring IP competence through hiring people with knowledge and expertise from IP-intensive companies in the same industry might, however, signal that the recruiting manufacturer is going into a similar technological field and that there might be a reason for the former employer to monitor the recruiting manufacturer's products or processes for potential IP infringements.

6.3.3 The Impact of I4.0 on Manufacturing BMs

Digitalisation is a way to create value and potential profit for manufacturers and their value chain, and in the past these were primarily engaged in relationships concerning non-digital technologies. The interviews revealed that this value creation can come from: (1) changed business models in the form of e.g. new digital sales channels for sales growth; (2) digital technology added into products making them smarter and more connected for customer value generation; and (3) improved manufacturing efficiency opportunities and reduced costs.

One way to understand the value enhancement from digital technology is through technological complementarity as defined by Teece (2016). For example, as digital technology in the form of sensors and processors is added to machines, this enables the machine to be run more efficiently through automatisation, more reliably through component status information, and more effectively as it can be adjusted easily through software settings. Also, an important additional result of the added digital technology is the resultant data created, which will be discussed further below.

The available literature indicated that the I4.0 levels of integration and data exchange between businesses will lead to extensive organisational consequences resulting in risks and opportunities to manufacturing business (Bauernhansl, Schatz and Jager 2014; Botthof 2015). The empirical data analysis is aligned to the literature in this respect and it also recognises that established manufacturers will be required to re-evaluate and innovate their BMs in order to stay competitive.

These changes to the manufacturing business models have been validated by this research, particularly regarding the points discussed in section 5.2.1 and 5.2.3, which as shown by the majority of interviewees will lead to new ways of creating value, disrupting the current value chain structures and the value appropriation regimes as demonstrated by the MARC Model analysis in Chapter 5.

Having discussed the impact on automotive manufacturers' business models, attention will now turn to the next research sub-question which focuses on the impact on IPS.

6.4. I4.0 and IPS in Manufacturing

6.4.1 The Theoretical Gap

As argued in Chapter 2, the literature review shows that there is a gap regarding a detailed analysis of the impact of I4.0 horizontal integration on manufacturing businesses, business models and their respective IP strategies. This gap is evident particularly in respect of how well establish and developed the manufacturing business model is in the context of their position in the manufacturing value chain and their appropriation regime positions. Addressing this gap is critical in order to understand how IP strategies can be adjusted to protect innovation and to boost the manufacturer's performance in the I4.0 horizontally integrated value chains.

The literature demonstrates the paramount role of IP in the functioning of inter-organisational collaborative and knowledge exchange initiatives (Chesbrough and Crowther 2006; Hertzfeld, Link and Vonortas 2006; Teece and Pisano 2007; Lichtenthaler 2010). Nevertheless, many areas, such as the relationship between the different types of IP (formal and Informal) at different stages of such initiatives, are still open and considered a topic for debate (van de Vrande, Vanhaverbeke and Gassmann 2010).

The literature also lacks a comprehensive account of the implications of I4.0 developments on organisational structures, collaborations and IP strategies supporting these business relationships (Kagermann, Wahlster and Helbig 2013; Brettel et al. 2014; Emmrich et al. 2015).

The literature is also unclear on the role of IP in the context of the new business models and highly collaborative inter-organisational business relations emanating from the implementation of I4.0, where large amounts of information and knowledge will be exchanged at unprecedented scales.

6.4.2 I4.0 and IPs in Manufacturing Empirical Findings

The data from the interviews demonstrate a perceived benefit that digital technology enables manufacturers to have a faster development rate, with frequent new generations of products and processes, thus making inventions and bringing them to market quicker. Regardless of whether the technology is developed faster, the time it takes to derive the appropriation strategies and to apply the protection mechanism remain largely the same, for example, a patent application process and the time to be granted a patent remains the same, between three and five years in the UK.

In a fast-moving technology field, waiting for a patent to be granted makes less sense. As digital technology is developed more quickly than non-digital technology, new digital products arrive to the market faster. This increased frequency of product launches or improvements presents a problem as to whether a new technology should be protected by IP rights such as patents.

The lengthy patent application process means that during the period it takes to get a patent granted, a new technology or product may have replaced the original technology under application and as a result the manufacturer is unlikely to recover the costs of innovating and filling the patent.

This evidence from the data analysis also contributes to the literature and addresses the gaps highlighted in the Table 24 above (LRT2 and LTR3) as it demonstrates an impact of I4.0 horizontal integration on manufacturing businesses, business models and the transformation of their respective IP strategies and appropriation regimes.

The data shows that for the manufacturers interviewed in this study, non-digital inventions are the only form of patented inventions. This fact ties into a proprietary strategy logic, where patents are the most used form of IPR which is traditionally utilised to achieve robust protection of a physical innovation.

Interviewees considered the same protection strategy less relevant as digital technology becomes increasingly important due to the fast-paced innovation. However, patents still are the most recognised protection mechanism by manufacturers, who also pointed out that having a patent portfolio, can be useful to ensure their freedom to operate and to avoid litigation. This view is aligned with the studies performed by Hall and Ham-Ziedonis (2001).

The findings emerging from the interview data also contribute to the literature regarding IP strategies in the Automotive manufacturing industry as it points out that there is limited knowledge and application of multiple protection mechanisms amongst the interviewees. As examined in Chapter 2 intellectual property include various protection mechanisms such as patents, trademarks, design rights, copyrights and trade secrets. It is also important to recognise that a combination of these different protection mechanisms should be utilised by manufacturers to provide the most effective protection to enable value appropriation in a particular innovation.

Furthermore, the research findings demonstrate that all manufacturing businesses interviewed are implementing digital technology in their products and forming new collaborations with new partners from across the value chain.

A typical example emerging from the interviews were the scenarios where the Technology Partner has developed a product innovation an OEM, who in turn, need the support of a Tier 1 Manufacturer improve the design to mass manufacture the product. These products were increasingly complex in comparison with current products being made by the Tier 1 Manufacturer and more often than not, included a mix of software, hardware and technical knowledge which was distributed across the value chain.

This highlights another important contribution to the literature on manufacturing IP strategies, the fact that due to these changes in the collaborative nature of horizontally integrated value chains a wider set of IPRs should be utilised by the manufacturers to protect their products, processes and services. These should include a set of formal and informal means of protecting innovation. On the other hand, the formal types of IPR such as patents, which are the most recognisable form of IP amongst the interviewees, should be used with increased caution as these methods require disclosure, which provides the competitors with an insight into the business and its value chain strategy.

It is argued that based on the low level of awareness demonstrated in the interviews, manufacturers should be more aware and skilled in the informal forms of protection, which as pointed out in the literature, are still a very effective way to secure value from innovation. For example, contractual agreements such as non-disclosure agreements with key collaborators or even employees which can provide further protection by preventing that key knowledge can pass across to competitors, as pointed out by Hurmelinna-Laukkanen and Pumalainen (2007).

Furthermore, as manufacturing businesses engage in more complex forms of collaborations across industries and value chains, as in the case of collaborations between software companies and manufacturers, the interviewees demonstrated a lack of clarity of what motivates the software businesses (what their business model is) and how they plan to monetise any data or knowledge acquired during the collaboration with the risk of such businesses emerging as potential competitors, suppliers, and so on.

6.4.3 The Impact of I4.0 on Manufacturing IPS

In conclusion, there is clear evidence from the findings from this study that the landscape for manufacturers is more complex, resulting in a transition over to innovation value chains. These will in turn cause additional complexity, as each individual business needs to acknowledge the strategies of other actors in these innovation ecosystems, as also pointed out by Holgersson et al. (2018) with regard to technology value chains.

It is argued that this study contributes to addressing the gap in the literature regarding manufacturing IP strategies in the context of I4.0 by showing that new strategies are needed as manufacturers enter more complex innovation value chains, especially regarding protection mechanisms and value appropriation regimes.

Another contribution is the evidence that despite the recognition by the interviewees of the fact that there is an increase in the level of complexity and collaborations, very few manufacturers in the study recognised the need to adapt their IP strategies to suit the transformation brought about by digitalisation.

In fact, the large majority of manufacturers still hold a very narrow definition of IP and do not show any evidence of using any form of value appropriation mechanism to recover revenue from their innovations in digital manufacturing. The manufacturers in the study that recognised the need to change mentioned the emergence of horizontally integrated value chains which bring together actors in an industry with different IP strategies, leading the manufacturers to make drastic changes and adaptations by putting a larger emphasis on complementary and substitutive knowledge and technology.

Finally, it is important to highlight that these transformative events in the manufacturing industry and the required adaptation of the IP strategy have been recognised by the literature as indicators of substantial changes to the appropriability regimes (Teece 2016). The next few sections will deal with the research findings regarding these changes.

6.5. The need to Adapt to Benefit from I4.0

6.5.1 The Theoretical Gap

As discussed in Chapter 2, the available IP literature focuses in large part on the protection of IP in relation to patents (Boldrin and Levine 2013; Moser 2013). However, patents are just one of the potential protection mechanisms available for automotive manufacturers. The literature lacks an empirical account of other mechanisms for appropriating value in the automotive manufacturing value chain. These include other formal methods such as trademarks, copyrights, and design rights, and also informal methods, such as secrecy, lead time, contractual agreements, and complexity.

Additionally, the literature does not provide an empirical analysis of the relationships between businesses in the automotive manufacturing value chains and the appropriability regimes. This empirical evidence is critical in order to identify the appropriate mechanisms (formal and informal), to address the challenges and opportunities resulting from the adoption of I4.0 and to define the manufacturers' IP strategies.

6.5.2 The Changes to Appropriability in Manufacturing Empirical Findings

The appropriability regime described above combines the different mechanisms to maximise value capture for return on investment on a particular innovation. The choice of protection mechanisms should be aligned to the business strategy and be unique for each manufacturer depending on their particular business model, value chain relationships and industry. It was evident through the data analysis that the interviewees have a limited understanding of how different protection mechanisms could support their strategies. The same was true in terms of efficacy (strength) of the mechanisms.

The data analysis demonstrates that as I4.0 technologies are implemented across the automotive manufacturing value chain, there is an increase in businesses collaborating and exchanging data regarding different technologies. In these scenarios, predicting the innovation project outcomes and the best IP strategy becomes a lot more complex. Additionally, the protection mechanisms used by manufacturers are also likely to increase in complexity.

To address this complexity, further combinations of different protection mechanisms should be developed by manufacturers. These could include for example a combination of data secrecy, which is an attempt to manage key information availability on a need-to-know basis, and improved contractual terms and conditions, which prevent knowledge sharing by unauthorised personnel.

The protection mechanisms utilised by the manufacturers should include a mix of prerequisite, derivative and supportive appropriability mechanisms. The mechanisms known as prerequisites, as the name says, are those which are required in order to enable other applicable protective mechanisms. An example of a prerequisite mechanism is that in order to patent an invention the inventor must ensure that the invention retains its novelty by protecting any early disclosure of the invention to external parties who are not bound by a non-disclosure agreement.

Derivative mechanisms 'buy some time' in order to derive an appropriate strategy and also to make use of competitive advantages such as shorter lead time to market. Using patents as an example again, this protective mechanism provides a monopoly protection for a manufacturer whilst the R&D teams can work in the next wave of innovation for products and services required to derive a competitive advantage for the business.

Finally, the protection mechanisms known as 'supportive' provide a level of support in combination with other formal and informal mechanisms such as the use of contractual agreements and IP training to support employees in their duties and responsibilities regarding confidential information which may lead to issues with patent applications and trade secret enforcement.

A key contribution of this study in addressing the gap in literature (LRT3) is that the findings point out that the manufacturers are not aware of the changes in the appropriability regimes demonstrated in the case studies (discussed in Chapter 5). Furthermore, in order to mitigate these changes, manufacturing businesses need to draft new strategies and suitable tactical processes required in order to effectively protect and generate value from their innovations.

The selection of protection mechanisms and IP strategy will provide a level of protection by raising the barriers for competitors to imitate. There are also other benefits associated with strategic opportunities for value appropriation such as the potential to generate revenue from licenses of protected technologies and other methods of monetising the data generated in the horizontally integrated value chains.

The manufacturing businesses should also consider the efficiencies and savings of selecting the right protection strategy, as the selection of inappropriate mechanisms may lead to very high costs. Patents for example take time and resources throughout the application process and even after they are granted, can result in expensive legal bills related to enforcement cases. The same logic applies for financial incentives to key personnel, which may preclude employees from leaving with key knowledge in the short term but will also affect the manufacturer's profitability.

A very important distinction for manufacturers to make when selecting the right protection mechanisms and setting their IP strategies relates to the distinction between incremental and radical innovation, which is critical to ensuring efficacy.

Typically, the protection mechanisms and the IP strategy in relation to incremental innovation which improves upon existing technologies in processes, products and services must be stronger than those utilised for the protection of radical innovation.

This difference is due to the fact that existing technologies tend to be easier to imitate by competitors and require a short time to commercialise due to the competencies in the value chain, the level of confidence and acceptance by existing customers. The opposite is true for radical innovations which are not yet proven and more complex to be replicated. In some cases, it is even an effective strategy to encourage sharing under certain conditions, as the wider adoption of the radical innovation can result in profits to the manufacturer.

Certain technology acquisition strategies appear to be more frequent and relevant than others. More specifically, the interviews reveal a large dependence on different means and types of collaboration for adding digital technology to their technology base. This high dependence on collaborations can be understood through the highly distributed technological areas needed to be combined (Yoo et al. 2012) before they can be further applied to their manufacturing products or operations. Further, to acquire lacking competences or technologies where flexibility in the application is needed in the exploitation strategies, collaborations are highly relevant (Lazzarotti and Manzini 2009), particularly in multi-invention contexts (Lazzarotti and Manzini 2009), such as those brought by the digitalisation in manufacturing.

The findings from the interviews demonstrate that there is a high level of uncertainty amongst the manufacturers regarding these collaborations, particularly in relation to issues of IP allocation, which are very common in the collaborations subject to the case studies in this research. These included, for example, who gets the resulting IPR on what, how the background IPR is going to be compromised in the exploitation of the resulting IPR owned by another party, how secrecy can be ensured from partners, and what partners can do with the knowledge they acquire.

The interviewees have shown evidence that the typical processes and IP management in manufacturing were designed to address simple relationships between two commercial partners. In such relationships, it is reasonable to assume that both parties want ownership of at least some IPR created to ensure the appropriability of value from the innovations they intend to commercialise. This finding is aligned to the literature in regard to pre-digitalisation and open innovation industries (Teece 1986; Granstrand and Holgersson 2014).

These findings support the literature which points out that in order to ensure appropriability, openness in terms of developed knowledge needs to be limited, as argued by Laursen and Salter (2014). In turn, in order to limit the risks, a range of protective mechanisms which goes beyond secrecy is needed, i.e. more complex contracts are required to govern the IP allocation between the parties.

On the other hand, collaborations require a certain openness between the involved parties in order to achieve the project objectives and for there to be a fruitful exchange of knowledge and capabilities. It could thus be said that manufacturers will have to be more aware of the strategies of each potential collaborator, the risks and benefits of exchanging knowledge and capability and the need to balance their openness and appropriability from innovative outcomes in collaborations.

These issues are increasingly relevant as the interviewed manufacturers engage in higher levels of collaborations to develop innovations in products and processes that involve digital technology than those that do not include digital technology.

It is argued that the roles of IPRs and a comprehensive IP strategy are an important enabling factor for collaborations between multiple partners and to achieve the levels of horizontal integration required by I4.0. Nevertheless, most of the manufacturers interviewed have a limited IP function within the organisation, and only rarely was this function observed to have a strategic role.

In almost every case, the IP function operated as a support function instead of an integrated part of the overall business. The protection mechanisms often focused on differentiating aspects of the business models, and the IP department had the responsibility of executing the direction of the business leaders and functional leaders.

This goes against the available literature, which presents the view that, by and large, IP management is, and should be, integrated with the business strategies (see Reitzig 2004; Al-Aali and Teece 2013; Somaya, Teece and Wakeman 2011) and that the IP department should utilise a mix of IPRs in order to achieve optimal protection (Al-Aali and Teece 2013).

The empirical data from this study also contributes to the literature (LRT3) as it demonstrates that the IP landscape and thus the appropriability regimes for manufacturers will be impacted by horizontal integration. This was evident in the shift towards a weak appropriability regime for Tier 1 manufacturers as demonstrated in Chapter 5 as part of the MARC Model analysis.

6.5.3 The Need for Alignment

Findings from the interviews demonstrated that IP is an increasingly important part of the manufacturing business. However, most interviewees have also shown a huge disconnect between their answers and their business practices identified through their contractual agreements and businesses structures. Also, even if the IP functions in manufacturing businesses view IP increasingly as an integral part of business strategy, there is no evidence in the contracts of interviews that these strategies are being aligned or integrated in any form.

Finally, it is argued that this section presents a substantial contribution to the literature addressing the gap in IP strategies in manufacturing (LRT3) by examining the issue from the perspective of a cross-functional sample of managers, which is different from the available literature in this field as it has mostly examined the cases from the perspective of IP managers and practitioners. This perspective also helps to elucidate the extent to which the appropriation regime for manufacturers will be impacted and as a result, understanding how the IP strategies can be adjusted to protect innovation.

6.6. The Main Research Question

What is the impact of horizontal integration on current manufacturing business models and intellectual property strategies and how these can be changed to address risks and opportunities?

The implementation of I4.0 is resulting in new challenges and opportunities for manufacturing businesses. This ongoing industrial revolution is based on the digitalisation of individual businesses and the networking of these digitalised businesses enabling collaboration via integrated system across the value chain.

When viewed from a business model perspective, manufacturers are faced with types of relationships, collaborations, contracts and networks where an unprecedented level of data will be exchanged across different businesses in the value chain. As a result, these relationships and collaborations lead to a new work environment and transform the work practices in the automotive manufacturing value chain.

These changes are important in regard to IP strategies, not only because the current manufacturing business are set up according to a pre-established framework, where the relationships are governed by contractual agreements, standard practices and procedures which control the interactions in the value chains, but also due the fact that unprecedented levels of integration and data exchange will bring transparency in the value chain to a level never seen before.

The researcher has created the following figure in order to show a comparison between a simple representation of the current manufacturing value chains and the future horizontally integrated value chains. On the left hand side, the figure shows a typical value chain where there limited interaction and data exchange between businesses in the multiple tiers resulting in 16 connections representing the current relationships of the 16 businesses in the value chain. On the left hand side, the figure shows the potential effects of a horizontally integrated value chain where there are multiple relationships with data and information exchange across all businesses in the value chain resulting in 256 connections representing the relationships in the same value chain.

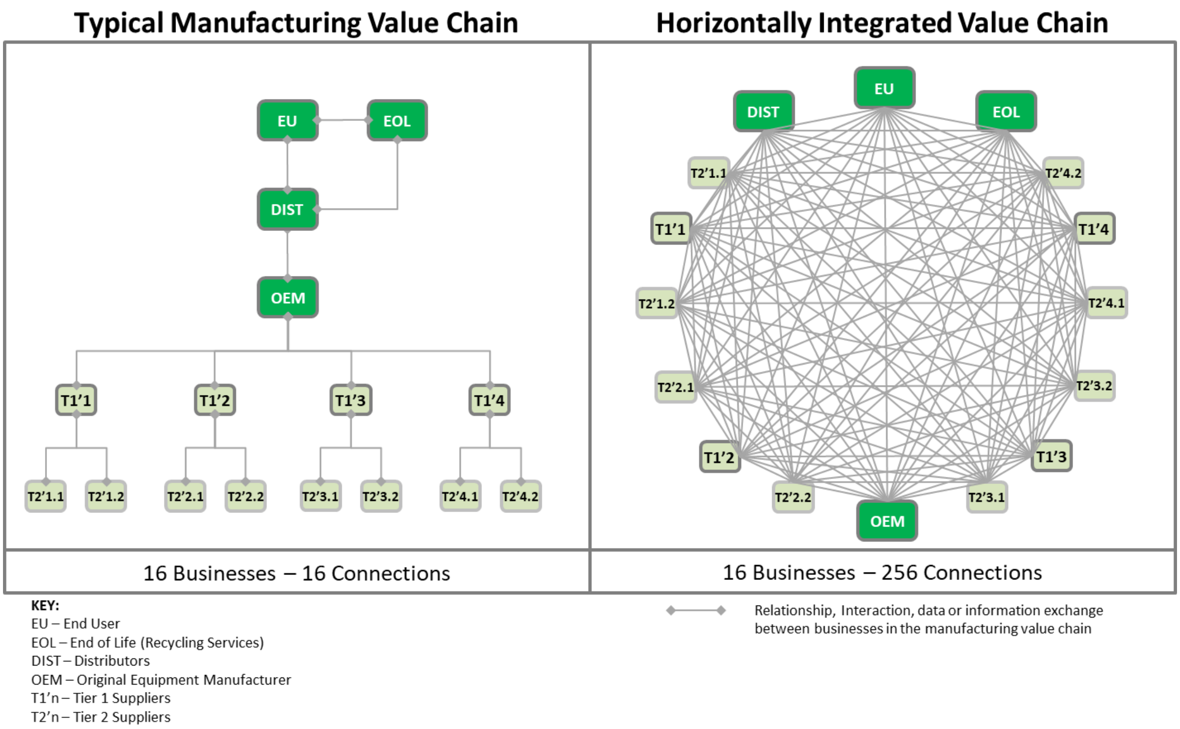

FIGURE 31 - MANUFACTURING VALUE CHAIN COMPARISON

The effects of digitalisation and integration in the automotive manufacturing value chain affecting the manufacturers' relationships should be carefully considered. An important area for focus is the standard contractual agreements, such as contracts for the supply of services and products, collaboration agreements and confidentiality agreements. These should be reviewed and their relevant terms and conditions should be adjusted to account for the new ways in which each business collaborates, and exchanges and uses data across the value chain.

These contractual agreements should provide a level of protection to current and future businesses relationships, where, for example, products are developed and made collaboratively with multiple businesses across the value chain. These contractual agreements should also consider where services are sourced via shared platforms and where most of the manufacturer innovation and operational data are stored in a shared cloud.

This transformation results in a number of challenges to IP strategy and management, as IP practitioners working in the manufacturing industry have historically used IP rights in the traditional sense, to protect the physical things, devices, structures and even the configuration of inventions embodied in physical systems or physical outputs, or the operation of physical systems, etc.

However, with the implementation of I4.0, the focus needs to be expanded to the IP protection of intangible things such as methodologies, virtual systems and its configurations, data ownership, data handling, data storage, algorithms, datasets, databases, brand, brand recognition, etc.

It is argued that the digital transformation resulting from the implementation of I4.0 challenges the current understanding and use of IP protection and commercialisation strategies in manufacturing. This change requires the development of new approaches that will be better suited to the rapidly changing, highly integrated business networks.

Such a position was clearly made in the Made Smarter Review issued in the second half of 2017, which recognises the importance of IP as a key intangible asset that can make up over 80 percent of the value of a manufacturer (Ocean Tomo 2015) and the fact that IP is often the key to securing a competitive advantage in globalised manufacturing value chains.

The review was commissioned by the UK government and led by Professor Juergen Maier (CEO Siemens UK), who also recognised that IP theft is one of the key threats related to the digitalisation of businesses (Made Smarter Review 2017). The review also points out that due to the intangible nature of IP, which is typically found in digital information, it is susceptible to digital piracy.

As the findings from the data analysis demonstrated, with the implementation of interconnected communications and the increase in manufacturer collaboration, manufacturing businesses are faced with the challenging task of carefully considering how to protect their IP, whilst at the same time how to facilitate interoperability between businesses in the value chain.

This researcher has developed and utilised the Manufacturing Appropriability Regime Construct (MARC) to demonstrate how the manufacturing appropriability regimes, and in turn, IP strategies, will be impacted by the horizontal integration, which will influence the business's ability to capture the value generated by an innovation.

Having discussed the impact of horizontal integration on manufacturing businesses and their appropriability regimes, attention will now turn to the recommendations for manufacturers embarking on the I4.0 journey.

6.6.1 Adapting to Address Risks and Opportunities

With the current rate of technological and industrial change, and the unpredictable nature of technologies involved in the I4.0 environment, a variety of techniques should be utilised in order to identify and protect IP.

Whilst there are a number of common strategies to be deployed in the area, it is important to emphasise that a one-size-fits-all solution does not exist, as each individual business performs to achieve its own strategic objectives and will be set up according to a particular business model. As such, it is recommended that the various protection mechanisms should be considered concurrently as part of a comprehensive IP strategy.

Manufacturers recognise that IP management involves a lot more than just law and legal knowledge. Even so, IP management is very commonly left to a particular technical or legal department within the business. These departments will typically focus narrowly on the protection of the business from potential infringement of other businesses' IP and the protection from the infringement of its IP by competitors.

In order to address the challenges posed by the horizontal integration of the automotive manufacturing value chains, the manufacturer's considerations in regard to IP strategy should focus on the particular business model and the IP required in order to achieve a particular value proposition in the context of the wider manufacturer business strategy.

The manufacturers must consider how to maintain a competitive advantage and retain the critical data associated with the sources of competitive advantage, whilst remaining open and responsive in regard to data sharing and collaborations in areas where the best strategic position is to share data in order to innovate fast.

6.6.2 Industry 4.0: IP Strategy, Policies and Management

Developing and executing a cohesive IP strategy is a very difficult challenge for manufacturers, particularly when embarking into the uncharted territory of the horizontally integrated value chains. Typically, businesses set their IP strategies at a very high level; however, in order for these strategies to be effective, they must be cascaded and impact all levels within a business, across all functions involved in everyday IP management decisions.

As demonstrated by the interviews, there is a clear disconnect between the strategic vision and planning and actual business practices which lead to decision-making within the manufacturing businesses. This leads to the lack of effective IP management for many businesses, where even the best efforts in developing an IP strategy can be ineffective if such a strategy is not built upon a foundation of policies, best practices and the appropriate management processes to execute the required IP strategy on a practical level.

The implementation of Industry 4.0, due to its pre-paradigmatic stage and lack of clarity, demands a level of flexibility from manufacturers. In order to achieve some degree of flexibility, the manufacturer's IP strategy must be aligned to the business objectives and include the required IP management policies to achieve the particular business objectives by utilising the correct IP processes and mechanisms.

These management processes should be guided by the appropriate policies and methods which provide decision-making support in all questions regarding IP in the context of the manufacturers' relationships in each individual circumstance.

Manufacturers must define the method of implementation and execution of IP strategy starting from the high-level strategy all the way to the policies, and from policies to the management processes. Manufacturers should also consider carefully the method of execution for the IP strategy as the policies and management activities require a more frequent level of review due to the nature of these new relationships.

Accordingly, it is recommended that manufacturers should consider how to formulate and adapt their IP strategies in order to address the changes in the appropriability regimes in the automotive manufacturing value chain on at least three distinct levels namely: IP strategy, IP policies, and IP management. Each of these levels will be discussed in turn.

The IP Strategy Level

At the IP strategic level, manufacturers need to define the high-level IP objectives in relation to the specific target markets, business areas, businesses models, technologies and knowledge areas. These strategic objectives must be founded on the manufacturer's business strategy, which should be broken down into objectives for each specific business area offering guidance to employees at all levels.

This is important in order to present a coherent view of how the manufacturer generates and captures value from each business area. It is also important that each individual within the organisation knows how the IP strategy supports the specific business model for each business area.

The manufacturers should consider that the IP strategies must be tailored to business areas that may be in different geographical locations and subject to distinct jurisdictions, as well as entirely different business models, such as a manufacturing consultancy or manufacturing design services, product manufacturing or other related services such as aftermarket parts production and distribution.

Furthermore, it is paramount that the manufacturers can identify the strategic objectives that require particular technologies and ensure that there is an alignment between the technology roadmap and development strategy with the IP strategy. It is critical that the IP strategy supports the technology and knowledge protection required in order to achieve the manufacturer's business models for each business area, not just for the current businesses, but also for the future.

The importance of a robust technology roadmap supported by IP surveys of the technological areas should not be underestimated by manufacturers considering new technologies and the development of new knowledge. Such a roadmap should be composed of a clear development and acquisition plan for on-boarding these technologies.

Manufacturers will need to recognise that each business area will have a specific combination of key technology and knowledge. In addition, only a proportion of this knowledge will be subject to formal protection with registered IP mechanisms due to the form and nature of these particular types of knowledge.

The same is true for different types of competencies, where the formal and registered IP mechanisms for protection do not amount to an effective and desirable solution; these include cases where there are high costs associated with the formal protection or where there are problems related to areas of technology prone to fast-paced development or in cases where the best option for protection is to keep the knowledge confidential and rely on trade secrets protection.

The IP Policies Level

In order to align the business strategy and the IP strategy, manufacturers must ensure that suitable IP policies are created to define the appropriate protection mechanisms required in order to achieve the IP strategy objectives and support the business model of a particular business unit.

Manufacturers should recognise that these protection mechanisms will vary between different business areas and business models. Businesses will have to carefully select suitable policies and mechanisms for each business area, and these policies should be maintained in constant alignment with the business model and the appropriability regime.

Another important aspect at the policies level, which should not be underestimated by manufacturers, is the IP valuation, firstly as an asset, but also in regard to its alignment to the IP strategic aims. This valuation in the context of the manufacturer's strategic objectives is critical as IP assets are very difficult to evaluate without the business model which indirectly aggregates and captures value from the particular IP asset.

This difficulty in evaluating IP assets without the business model context arises because there are many ways in which a manufacturer can utilise IP for value appropriation. For example, IP can guarantee a monopoly for a product in a certain market in the case of patents, but also on the other end of the scale, IP has embodied know-how protected by trade secrets that can be used as an asset in collaborations with partners lacking that particular knowledge.

The valuation of IP in a horizontal integrated supply chain is also difficult because two actors in the integrated value chain will very often have different views regarding the value of an IP asset. This is mostly because different businesses will have distinct business models and therefore different views of the business potential that could be realised by utilising the IP assets in current and future deals.

More importantly, IP assets can be used as proxy to an insurance policy and enable manufacturers to enter strategic markets without the risk of infringing other business's IP. In these examples IP is valuable in the context of the business strategy in the horizontally integrated value chains.

Finally, in a horizontally integrated value chain, IP can act as a badge of quality and innovativeness which can attract potential partners and collaborators who seek to develop products and services in collaboration. More importantly, the IP developed in connection with customers' and suppliers' products or services which are commercialised locally or globally can be a valuable source of additional revenue for manufacturers who could benefit from licensing IP to customers, suppliers and other third parties.

These are just a few examples of how value can be generated in the context of manufacturing business models in the horizontally integrated value chains.

The IP Management Level

Finally, the IP management level refers to the daily processes and activities which inform the manufacturers' decisions with regard to IP creation, evaluation, protection and commercialisation. The success of these processes will result in the success of the overall IP strategy. Likewise, any failure at the process level should inform changes to the IP management policies and processes to ensure that the IP strategy objectives are achieved.

In the dynamic environment of horizontally integrated value chains where IP in the form of datasets, drawings, 3D models, etc. are exchanged across businesses in the value chain, manufacturers must ensure that the IP management processes include the assessment of IP assets in the context of the data shared, as well as the data received.

Such an assessment is important in order to understand changes to the context in which the IP asset is being, or is planned to be, commercialised, as these changes might impact significantly upon the internal and external conditions, which can also influence the IP strategy. This assessment will ensure that the particular management approach is still relevant and that the IP in question is still relevant to the IP and business strategies.

Aligning Business, Technology and IP Strategies

For manufacturers entering the horizontally integrated value chains it is critical to ensure that there is a coherent link between the business, the technology and the IP strategies as this cohesion is paramount for the selection of the correct portfolio of protection methods to secure the critical knowledge required to achieve the manufacturer’s strategic objectives.

The IP strategy should explore the technologies identified in the business strategy and provide a definition of which technologies and knowledge are core to the manufacturer’s value proposition and how these IP assets should be created, evaluated, protected and commercialised. The IP strategy should also identify which technologies and knowledge are not core to the manufacturer’s value proposition and in turn can be shared and/or disposed of.

It is important that manufacturers recognise that the range of protection mechanisms required in the horizontally integrated value chains must include formal and informal methods. Special attention should be given to contractual agreements and practical means of protection such as encryption and access restrictions to critical information.

In the past, knowledge protection strategies across different businesses were very similar. However, it is important for manufacturers to understand that the actual IP strategies for protecting knowledge in manufacturing must be tailored to their particular business strategies and business models. For example, patents which are one of the most common strategies, still the most recognised IP protection strategy by manufacturers as demonstrated in the interviews.

Patent-based IP strategies provide very strong protection; however, this type of strategy is only effective for certain technology areas with certain life cycle characteristics. For example, in the pharmaceuticals industry, due to the long product cycles, patent-based strategies are a very effective method of protection and can provide the patent holder with a monopoly that in turn leads to a competitive advantage.

In comparison, in areas of technology with a shorter product life cycle, the same strategy is no longer effective as the period between a patent application and grant (typically two to four years) means that the technology could become obsolete before the monopoly is granted.

The formal protection mechanisms for IP protection are still an important part of the IP strategy toolbox for manufacturers. For example, patents will be important for manufacturers where they wish to gain exposure and improve the value of their brands by being recognised as a leader in innovation in a particular field. However, it is also important for manufacturers to recognise the value and benefits of informal protection mechanisms in the context of data exchange in horizontally integrated value chains.

Methods such as publishing innovations or faster innovation cycles can be a source of protection and competitive advantage in certain technological areas. For example, publishing or sharing a particular innovation or technology know-how is a strategy used when the particular innovation or know-how is not core to the manufacturer’s value proposition, but where it could attract collaborations which could lead to strategic development of products or services in an area of relevance to the business.

This strategy can support the manufacturer in creating a demand for products or services, create the pull for a collaborative research and most importantly, remove the novelty element on the topic of publication and create a barrier against potential patents in the area by competitors.

Finally, secrecy is a very important weapon in the manufacturers' protection arsenal. This mechanism relies on identifying and maintaining secret key technologies and knowledge. The manufacturer should seek to avoid sharing this key technology and knowledge, both internally (amongst employees and contractors) and externally with customers and suppliers.

Once again, the emphasis is on identifying the critical knowledge required to achieve the manufacturer's value proposition and controlling such knowledge very tightly. It is a key function of the manufacturer's IP strategy to identify who should have access to what knowledge internally and externally.

Most importantly for manufacturers, contractual protection methods are paramount in horizontally integrated supply chains. Regardless of the particular businesses model, the manufacturer is likely to increase the data exchanges and innovation activities within the partners in the supply chain, all of which are formalised through contractual agreements.

Manufacturers should ensure that they are not bound by onerous clauses in old contracts which render IP appropriation impossible. Such contracts are common practice in automotive manufacturing and were evidenced in the data collected for this research. In these scenarios the manufacturer signs up to transfer any IP generated in relation to a particular product or production process to the customer, including all formal and informal IP.

Unless manufacturers have a business model which does not rely on value generation from IP assets, one must be aware of these agreements and ensure that they are renegotiated before embarking on the creation of horizontally integrated value chains. Failure to do so will mean that the manufacturer will be placed in an extremely weak appropriability regime where the business will be unlikely to appropriate any value from innovation.

On the other hand, manufacturers should also be aware of new agreements which must include clauses on confidentiality, ownership of background and foreground IP, definitions of rights to use all forms of IP, noncompetition, etc. A number of suggestions and recommendations in this area will be discussed in section 6.6.3 below.

Such agreements between manufacturers and their partners only protect IP externally in relation to contracting parties. However, manufacturers should also be aware of IP protection in relation to key members of staff as the risk of key knowledge leakage is greater due to the codification and sharing of knowledge across departments in the entire organisation.

This form of internal IP protection must be governed by strong contractual clauses in the employment contract to prevent employees from breaching confidentiality, appropriating inventions and competing with the manufacturer.

The following paragraphs contain a non-exhaustive list of recommendations that are aimed at addressing some challenges highlighted in the previous sections with a view to improving the appropriability position of manufacturing businesses and their IP strategies in the I4.0 interconnected environment.

6.6.3 Practical Recommendations for Data Protection in Manufacturing

The success of horizontal integration is reliant on vast amounts of data shared and aggregated across the entire manufacturing value chain. The rights to the individual datasets, as well as the bigger aggregated datasets and the knowledge and information emanating from them, are of critical importance to businesses.

In order to address this challenge, it is argued that a non-exhaustive set of actions that can improve the appropriability position and the protection of manufacturing businesses' intangible assets in horizontally integrated data exchanges within a value chain (Soares and Kauffman 2018).

Recommendation 1 - Categorise the different data types in contracts

Manufacturing businesses should be aware of the main data types to be shared in these inter-organisational relationships emanating from I4.0 and implement appropriate measures to protect each type. In this regard, it is recommended that contractual terms between manufacturing businesses and the supply chain regulating the exchange of data should cover at least the data types listed below:

1) Raw data, machine data and unprocessed data

This type of data refers to research and development and also to operational data generated by machines and other devices;

2) Analysed/Processed data

This type of data refers to the analysed or processed data generated or held by any business in the value chain (suppliers, manufacturers, customers, end users); and

3) Manual/Input data

This type of data refers to the manual data input by users of connected machines and business systems across the value chain.

Recommendation 2 - Review the IP ownership and protection clauses

Manufacturing businesses should consider the fact that, similar to joint IP ownership clauses, data ownership and rights clauses contained in I4.0 contracts will be the subject of much negotiation. These will often be contentious negotiations, as the powers of the various parties in a value chain will influence how much each party will be commercially pressured to share or transfer.

Nevertheless, such contracts and their clauses governing the sharing and ownership of data should at least consider the following ownership, rights and licensing constructs:

1. What data is subject to the contract?
2. What rights are allocated to which party to the contract?
3. What specific IP is owned or licensed to which party?
4. Who is the licensor and who are the licensees?
5. What are the licensees' particular business?
6. What products and which industries do they offer/operate in?
7. In what territory?
8. What is the term (time) of such a right?
9. Are the rights exclusive or non-exclusive?
10. Is there a right to sub-license?

Manufacturers should evaluate their particular business strategies and the impact on their appropriability position in order to select and include these constructs in the particular contractual agreements with suppliers, partners and customers.

Finally, it is also important to define the expectations, responsibilities and liabilities regarding data security and privacy, as both suppliers and customers could increase the chances of a cyber-attack resulting in a data breach. The contracts should incorporate such expectations, responsibilities and liabilities very clearly and carefully. They should include the details regarding gathering, anonymising, notifying and using suppliers', partners' and customers' data.

6.6.4 A Model for Improved Value Appropriation

As discussed and demonstrated through the MARC Model in chapter 5, the I4.0 will adversely impact the appropriation regime for Tier 1 manufacturers whose IP assets will be affected to varying degrees depending on the different technological or knowledge areas.

IP in the context of horizontally integrated value chains should be used as a method of value appropriation for manufacturers to secure a return on investment in innovation. As such, the IP strategy should be tailored to account for the differences in each business areas and business models, thus generating a portfolio of IP assets, each with the necessary protection mechanisms and commercialisation/sharing strategies.

Manufacturers should, in turn, develop a coherent and agile IP strategy which aims to match the technological competencies required to remain competitive in the current target markets, as well as the potential future market needs.

With this challenge in mind, the researcher has developed the I4.0 Business and IP Strategy development framework which can be used to support manufacturers to address some of the main issues faced in the context of value appropriation in the horizontally integrated value chains. This framework also brings additional benefits regarding the alignment and communication of business and IP strategies across the organisations.

The following IBIPS framework has been developed to provide manufacturers with a model for linking business strategies to business models and to IP strategies as depicted in the following figure.

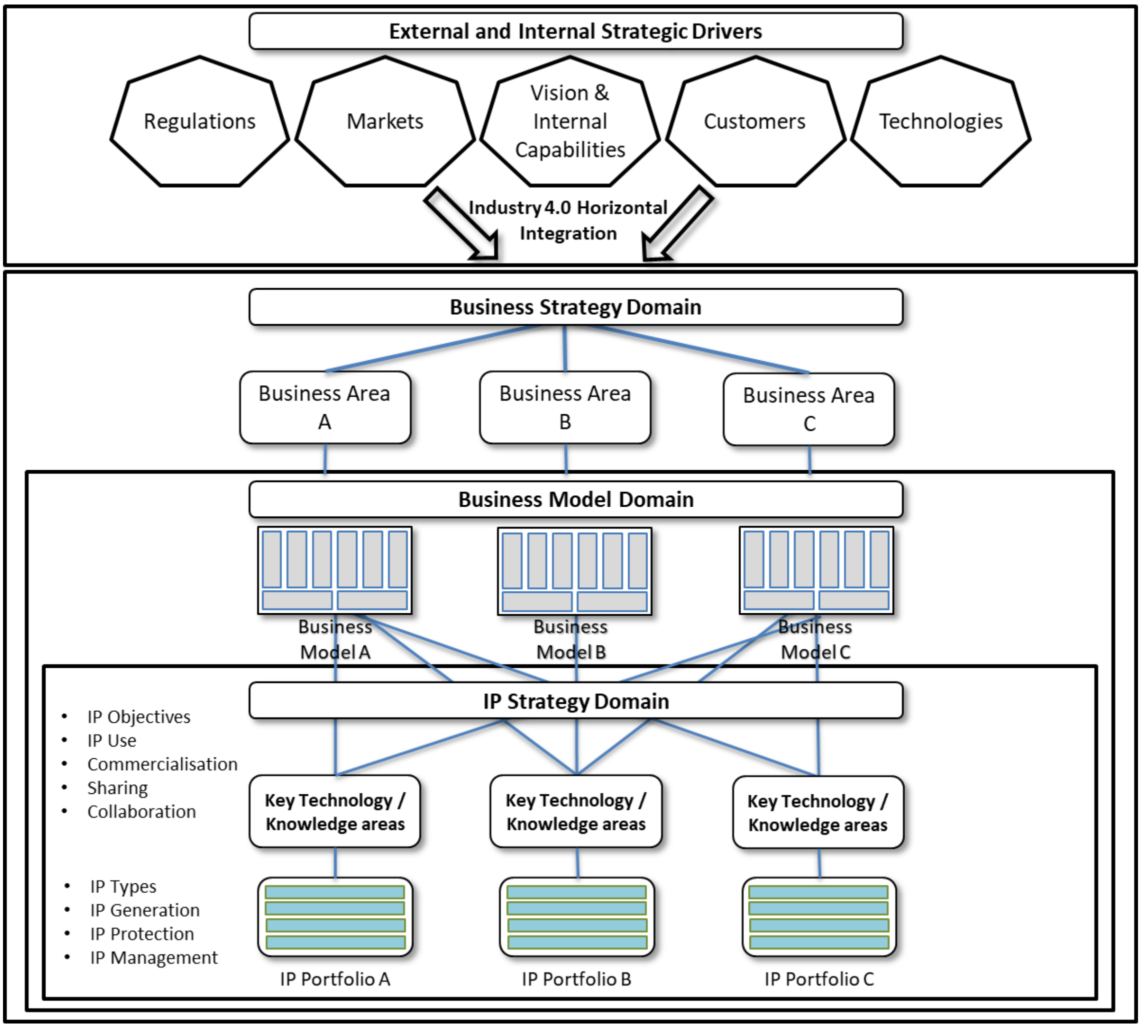

Figure 32 - IBIPS Framework

As depicted in the above framework, the manufacturer should begin with an evaluation of the external and internal drivers influencing their business strategy (External and Internal Strategic Drivers at the top). Once these factors are taken into account, the manufacturer should create an overarching business strategy which in cascaded into each business area which will execute the business strategy (Business Strategy Domain in the second level from the top) via a particular business model.

From the business model, shown in the Business Model Domain, the manufacturer will be able to identify the core technological or knowledge areas required to achieve a particular value proposition. Once these areas are defined, the manufacturer may want to establish the necessary level of control over the required IP (IP Strategy Domain) to enable the successful functioning of the particular business model.

Furthermore, the manufacturer may also decide to tailor the level of resourcing and investment in these areas. It is also important for the manufacturer to identify where certain IP assets are not required by the manufacturer in order to enable a particular value offering as such assets can be licensed from other technology partners.

Manufacturers should also be clear and precise regarding their appropriability stance in partnerships, relationships and collaborations with different IP assets relating to distinct technology and knowledge areas. This clarity is important, as IP in certain knowledge and technology requires collaborative development.

In certain circumstances, due to existing knowledge, capabilities and strategic positioning, manufacturers may choose to avoid conflicts and loss of competitive advantage as competitors with the similar knowledge, capabilities and strategic positioning within the value chain are more likely to benefit from the IP shared during the relationship.

Manufacturers should identify and classify in order of importance all the technologies and key knowledge required currently and in the future to support the current and future business areas and business models. This identification must be based on the current and future markets which the manufacturer wishes to serve directly via products and services or indirectly via IP licensing.

It is also important for manufacturers to recognise that they will require several technologies and competencies in key knowledge areas in order to enable each business model; for example, in order to manufacture products in the case studies used in this study, the manufacturers required IP in technology and know-how across materials, products, processes, etc.

On the other hand, it should also be recognised that a single IP asset can be utilised have intrinsic value for multiple business models within the same organisation and manufacturers should utilise their IP strategy to identify how each individual IP asset relates to each business models and the overall business strategy. This aspect is critical in order to ensure that the IP assets are being protected and managed effectively.

In addition, a coherent IP strategy should define which IP assets need to be acquired from external sources, as well as which IP assets the manufacturer can commercialise using a technology transfer to external partners and the areas in which the manufacturer needs to collaborate with technology partners to develop IP assets.

The increase in IP assets developed with partners is one of the key changes in the horizontally integrated supply chains which affects the current manufacturing IP strategies and demands new thinking beyond the traditional IP strategies, solely based on registered IP such as patents, as these traditional strategies do not provide effective protection in the cases of collaborative co-creation.

These traditional strategies are typically too rigid and fail to account for problems emanating from the lack of control which results from the high volumes of data and knowledge exchanged in horizontally integrated value chains. In addition to the volume of sharing, the new IP strategies require more flexibility to account for new business models that emanate from connected value chains and impact the business strategies and objectives.

These new business models which result from the development of collaborative innovation can be commercialised in different ways, most of which are unfamiliar to the traditional manufacturers. This is the case particularly for traditional Tier 1 and Tier 2 manufacturers in the make-to-print business models.

As discussed throughout this section, the fact that IP will be increasingly important for manufacturers in the collaborative setting is undisputed. This will lead to an alignment of the manufacturing industry with other high-value industries where technology development relies on complex collaboration and cross-licensing of IP rights. However, another challenge to manufacturers is that, particularly in the automotive manufacturing value chain, the practices surrounding IP use and commercialisation are somewhat immature and IP ownership can be seen as a drawback.

The following quote is an example, in the words of a manufacturer:

> "We had worked on this collaboration project with a customer and shared a lot of knowledge which enabled our team to identify an improvement to the product which was co-developed with the customer.
>
> We went on to file a patent and after filing we have informed the customer in respect of this new technology which can provide a significant improvement to their product, but the customer wasn't receptive of such an approach and the whole situation was very delicate. They did not like the fact that we had control of IP with such an impact on the customers' or a potential competitors' product."

The success of manufacturing businesses in the horizontally integrated value chains requires a wider consideration of the entire business case for the network and each partner's relative position. As such, stronger protection of IP by the manufacturer will not necessarily lead to a benefit to the wider supply chain.

The MARC Model developed as part of this research contributes to IP strategy and appropriability theory by addressing the gap regarding the impact of horizontal integration on manufacturing business models and IP strategies. Furthermore, it also supports manufacturers in practice by providing a tool which enables them to perform an assessment of the appropriability regime and to consider, given their particular business model and IP strategy, the likely position of each business in the immediate horizontally connected value chain.

Another important contribution to theory and practice provided by the MARC Model is that it can highlight the effectiveness of both formal and informal IP protection mechanisms and strategies which will depend on the particular business strategy and business model. As such, patents may be very effective for one manufacturer given its wider context (business strategy, business model and particular areas of technology), but not effective at all for other manufacturers to whom patents may only bring unnecessary costs and future risks related to patent litigation.

In addition, the framework can also demonstrate that, in certain business models, informal protection mechanisms and the use of well-crafted contracts is the most effective method of protection and should be a more prominent part of a manufacturer's IP strategy as it can offer better protection to digitalised knowledge contained in datasets and know-how.

Finally, another important consideration for manufacturers is that due to increased competition as a result of the proliferation of technologies improving operational efficiencies and the harmonisation of systems across the value chain, the manufacturers may increasingly adopt strategies to commercialise complementary IP via licensing agreements. This would allow manufacturers to generate an alternative source of revenue through licensing the non-critical innovation within their value chains.

In such a strategy, formal protection mechanisms such as patents are still relevant and should support manufacturers to appropriate value in the horizontally integrated value chains. This is a common thread across many high-value industries where increasingly manufacturers and their collaborators successfully develop and commercialise technologies via licensing to other manufacturers who are interested in making and commercialising the physical products in the same or in an alternative value chain, market or industry.

6.7. Chapter 6 Conclusion

The traditional IP strategy for manufacturing businesses was, for a long time, too concentrated in achieving the highest possible level of protection for its innovations. In contrast, in today's horizontally integrated value chains where manufacturers have to increasingly collaborate with a number of partners exchanging their data, key knowledge, and technology, the high levels of protection once sought should no longer be the main objective of a manufacturer's IP strategy, but rather the protection of the critical IP required to achieve the current and future strategic objectives.

Whilst the adoption of I4.0 technologies have no effect on the way the various forms of IP themselves operate, they do affect how businesses relate to each other, and in particular how data and knowledge containing IP are exchanged between manufacturing businesses and their value chains.

As explored above, the current theory and practice in this field do not provide manufacturers with a clear and coherent model to link business strategies, business models and IP strategies required to address the IP challenges and the change in the appropriability regimes for automotive manufacturers in the face of horizontal integration of value chains. As such, manufacturers will need a new way of thinking to support themselves in exploring the new requirements and solution for IP protection and value appropriation utilising a wider range of formal and informal mechanisms.

In this new environment, manufacturers should not look at IP strategy just to achieve tight protection, but instead to enable control of and access to critical IP assets necessary to derive a competitive edge and enable value capture by the manufacturer. As discussed above, the formula to achieve this is varied and will differ from manufacturer to manufacturer and from business model to business model. At times, the key innovation developed by the manufacturer will be commercialised through licensing agreements which will enable value capture via indirect sources.

A resilient and successful IP strategy in manufacturing will be aimed at supporting the manufacturer’s business strategy and enabling the particular value proposition required by each business area and business model. The use of a traditional, one-size-fits-all IP strategy which is rigid and focused only on the strength of particular protection mechanisms is a sure recipe for failure.

What do horizontally integrated value chains, and the increased levels of data and knowledge exchange mean for manufacturers and their strategies? It means that the new relationships and all aspects of collaborations, as well as the data and knowledge to be exchanged, should be carefully considered in combination and in the light of the business’s IP strategy in order to ensure alignment to the manufacturer’s business strategy and business model.

7. Chapter 7 - Conclusion

7.1. Introduction

The research aimed to make an original contribution to the theory and practice in the areas of manufacturing business strategy and intellectual property management and strategy. Firstly, by demonstrating through primary data, the impact of Industry 4.0 on business strategies and intellectual property management. Secondly, by providing two new methods to support automotive manufacturers adopting I4.0, the Manufacturing Appropriability Regime Construct (MARC) and the I4.0 Business and IP Strategy Development Methodology (IBIPS).

The study was designed in order to address the theoretical gaps highlighted in the literature review in Chapter 2, and also to deal with the challenges faced by senior managers and IP practitioners in the automotive manufacturing industry. Finally, as with any PhD research, this project has also sought to satisfy the academic standards and to deliver a set of findings that provide practitioners with relevant information of high quality, as typically provided in projects in the field of management research (Pettigrew 2001; Worrall 2005).

The data gathered from the interviews and contractual analysis reveals a number of interesting perspectives that in the light of earlier literature provide a number of important key findings. These findings are relevant for both academics and decision-makers in the areas of business management, automotive manufacturing businesses, as well as, in IP management. They demonstrate the impact of I4.0 on manufacturing businesses and their IP strategies in the face of this change in paradigm. This has allowed both a contribution towards addressing the theoretical gaps and the practical difficulties encountered by practitioners in the context of this research.

The tools and methods developed as part of this research build upon previous knowledge and contribute new knowledge which can aid businesses evaluating the appropriability regime dynamics in their specific contexts and the creation of a cohesive business and IP strategy link. The research suggests that the applications of MARC and IBIPS can support manufacturers in overcoming some of the main issues in the context of value appropriation in the horizontally integrated value chains. These tools can also provide additional benefits regarding the communication of these strategies across their organisations.

Manufacturers can use the MARC model to evaluate past, current and future collaborations in the context of their relationships with partners and collaborators across their value chains in order to identify their appropriability regime position and the likelihood of appropriating value from the innovation emanating from the collaborations.

Furthermore, once the appropriability position is identified, the manufacturers can use the IBIPS to derive a clear strategy for the future, in order to improve the links between the business strategy, business model and the IP strategy and, as a result, improve the likelihood of appropriating value from their innovation.

This chapter is designed to provide an overview of the findings and their contribution to theory and their practical implications. Finally, the research limitations and potential topics for future research are also discussed.

7.2. The Research Contribution

As this study's main purpose was to address the gap in theory and practical challenges driven by the implementation of I4.0 in the automotive manufacturing industry, it was paramount that the research achieves the double hurdle expected of high-quality research in the businesses strategy and management with regard to academic rigour and actual practical relevance denoted by both Pettigrew (2001) and Worrall (2005).

As demonstrated in the previous six chapters of this thesis, this research project satisfies academic rigour and practical relevance in the following manner. First, the researcher undertook a multi-disciplinary literature review, and used transdisciplinary lenses to analyse and develop a research approach and identify a potential solution to the research problem which improved the rigour of the research.

Second, the academic rigour was improved by the approach taken to the design of the research methodology, which utilised data collection triangulation as described in Chapter 3 section 3.4.2.3. This approach focused on data collection and analysis using multiple sources and multiple methods of analysis in order to improve the validity of the research.

The research framework was designed to demonstrate the key areas of theory which were explored and provided important sources of material, which was synthesised to achieve a theoretical model fit for the purpose of addressing the particular research questions which this study set out to answer. This interdisciplinary approach and the methodological choices were designed to improve the academic rigour and to ensure the delivery of a practical output and its relevance to the manufacturing businesses which were the focal point of this study.

7.2.1 Contribution to Knowledge

The identification of an original contribution to theory is not an easy task, particularly for the uninitiated conducting his first doctoral level research project. As such, the researcher has looked for inspiration in literature and identified 15 types or modes of an original contribution to knowledge in the work of Phillips and Pugh (2000) which are typical of doctoral researches such as this.

This research provides an original contribution in five main areas, which will be discussed in the following sections:

I – This research adopts a multidisciplinary approach and explores the issues affecting manufacturers through the shift to Industry 4.0, from a perspective of new business models and intellectual property theories. This work is original and, as explained in Chapter 1 contributes to the understanding of the change in paradigm affecting manufacturers entering into Industry 4.0 horizontally integrated supply chains.

This research contributes to the business models, IP strategy and appropriation regimes in regard to digitalisation of value chains. It provides empirical evidence and conceptual models that shed light on the acknowledged gap regarding management research on the impact of Industry 4.0 at a business model level (Brettel et al. 2014; Emmrich et al. 2015; Arnold, Kiel and Voigt 2016).

The research inquiry was focused specifically on identifying the impact of digitalisation on automotive manufacturing businesses and how this transformation is affecting their business models and IP strategies. As discussed in Chapter 2, the available literature does not provide such empirical evidence or any theoretical models to evaluate such impact and so this contribution is novel.

II – This research carries out and presents empirical work that has not been performed prior to this study. There is no evidence emanating from the literature regarding Industry 4.0, business models and IP strategies that a relevant study has been conducted in respect of the impact of horizontal integration on manufacturers and their appropriation regimes. As such, this study is the first to consider the way in which the manufacturing value chain is being transformed by horizontal integration and how that is affecting value appropriation by manufacturers in the automotive industry in the UK.

The research provides empirical evidence from practitioners involved in the management of businesses in the UK automotive manufacturing supply chain that demonstrates the status and impact of Industry 4.0 implementation on their value chain. This is the first documented account whereby data from a business perspective of this change in paradigm in the automotive manufacturing industry was collected and analysed. This study will support further theory building and research into manufacturing strategy, IP strategy and appropriability regimes.

The key empirical findings provided by this work include:

i- The current state of Industry 4.0 implementation in the automotive manufacturing industry in the UK

ii- The impact of Industry 4.0 horizontal integration on automotive manufacturers in the UK

iii- The understanding of intellectual property and current practices in the automotive manufacturing industry.

III – This research also provides a unique synthesis of extant literature and new empirical data analysis that has not been carried out prior to this study. In particular, this research provides a cross-disciplinary synthesis of academic literature to offer a new perspective on the impact of the fourth industrial revolution on automotive manufacturers in the UK.

The research builds upon the theoretical and practical gaps identified in the literature review and data collection. A conceptual model to support the assessment and evaluation of manufacturing appropriability regimes was developed and applied to four case studies.

This conceptual model contributes to the business model theory as a tool to link value appropriation at a conceptual level, to the practical means of appropriating such values in the context of a value chain. This also contributes to the theory of appropriability regimes as it developed a procedure to assess and plot the positions of each business in a particular value chain.

Furthermore, this conceptual model also contributes to the theory in IP strategies as it provides a tool to identify the impact of protection mechanisms and the efficacy of IP rights in relation to different business models and appropriability regimes.

This model highlights the importance of business model theory and IP strategy as an integrated approach to value appropriation, not only by developing a theoretical approach but also by applying such an approach and setting a theoretical foundation to underpin future multidisciplinary research in the area of digitalisation and value appropriation. This latter point is a particularly unique aspect of this research and provides a key original contribution to knowledge.

IV - The research also provides a key contribution to theory by identifying the key indicators for the successful alignment of business and IP strategies. Such an alignment is required in order to improve value appropriation and the creation of an IP strategy model that describes how manufacturers can integrate their business strategies and IP strategies in order to maximise intangible asset protection and value generation.

These indicators were generated as a result of the literature review and current practices observed during the interviews and work of the researcher in the automotive manufacturing industry. The theory and practice observed as then synthesised and a conceptual model for business and IP strategy alignment was created.

This list of indicators was then incorporated into the appropriability regime analysis framework, which was further developed and validated through the application of the four case studies in the automotive manufacturing supply chain in order to improve their strategic alignment and their prospects of value appropriation through intellectual property.

V - This research has also made a significant contribution to the existing literature via the outputs published in two posters, three papers presented in peer-reviewed conferences, five lectures and three peer-reviewed journal articles. These outputs are presented in the appendix of this thesis as evidence that a contribution to knowledge in the disciplines studied, as well as to practice, has been made by this research.

The next few sections will provide a discussion on the research limitations, future research agenda and contributions on the IP strategy model to support manufacturers in a new approach to business and IP strategy alignment in order to maximise their chances of value appropriation in horizontally integrated value chains.

7.3. Research Limitations and Future Research Agenda

This project has uncovered a number of relevant areas within the IP strategy and value appropriation fields in relation to manufacturing businesses that could be subject to further research. The next few paragraphs will provide a brief discussion of some of these potential areas for future research.

First, this study showed that manufacturers are increasingly perceiving the importance of intangible assets, and their value is an important topic for research, with high relevance to managers, not only in the automotive manufacturing industry but also in many industries being affected by digital transformation and integration. As such, future research could focus on collecting evidence demonstrating the impact of intangible assets in manufacturing long-term competitive advantage, as well as financial performance.

Second, this study lacks sufficient data on how data is actually managed between manufacturers connected via a horizontally integrated value chain. This is due to the fact that the manufacturers interviewed are still in the early days of horizontal integration and the data currently exchanged is not proactively managed in most of the cases. This, however, creates a demand for future research focused on the development of a theory and frameworks for data management in horizontally integrated value chains.

Third, as mentioned before in this chapter and extensively in Chapter 3, the relevance and validity of this research has been a consideration since the conception of this project, and proactive measures have been taken to improve the validity by utilising multiple theories, methods, datasets and analytical methods. Nevertheless, there are still limitations to this study due to the fact that the research outcomes could not be extensively trialled in actual horizontally integrated relationships in the manufacturing value chains.

In a final effort to address this limitation, the Appropriability Regime framework has been explained in a post-interview meeting with two interviewees from each business involved in the case studies, all of whom independently scored and compared the position of their particular business in the framework, as well as in relation to the practical value of the theory for real-life applications in the manufacturing industry.

The researcher has identified further opportunities to test the tools and theories resulting from this research in practical projects; however, time limitations meant they could not be conducted within the timescales for this project. This is an area where future research could be conducted to further test and validate the MARC Model and the IBIPS framework with a wider range of projects over a longer period.

In regard to the direction of future inquiries, an investigation could be undertaken into whether the evidence in the empirical data from the automotive manufacturing industry is aligned with other manufacturing industries and whether there are best practices to be shared across different manufacturers.

In the same vein, a study examining international automotive manufacturers within a multi-jurisdictional value chain could expose further complexities which may affect automotive manufacturers with horizontally integrated global supply chains.

This could include a longitudinal study involving an evaluation of the efficacy of the tools and theories developed to assess the appropriability regimes for manufacturers.

Another interesting avenue for future study could investigate whether the contractual agreements and the law in different jurisdictions could cause further risk to the manufacturers' probability of appropriating value in horizontally integrated value chains.

7.4. Policy Implications

The empirical findings from this research can be used to derive a number of suggestions to influence government policy in respect of value appropriation in the manufacturing industry.

First, there is a need to establish a programme to provide basic IP training focused on value appropriation for manufacturing businesses and their value chains. This is critical to ensure that future investment in innovation in the manufacturing value chain is not lost to manufacturers in other economies such as low-cost countries who could potentially benefit from IP appropriation through horizontally integrated value chains.

Second, government initiatives such as the Made Smarter Review, which actively encourage the adoption of digital technologies by manufacturers, should also provide an impact assessment of changes to the manufacturers' relationships in the value chain and offer advice on how to mitigate risks related to IP strategies and value appropriation. Furthermore, the provision of model contractual agreements and contractual clauses to govern the ownership of data shared across the value chains should be provided by such initiatives to support particularly small and medium manufacturers who have limited resources at their disposal.

Third, the government should actively encourage IP training as part of the curriculum for professionals in the manufacturing supply chain. This research provides evidence of the lack of understanding of IP in the manufacturing industry, which directly affects the probability of value appropriation in this industry. The provision of guidance to universities and colleges as well as the provision of courses for manufacturers (which could be subsidised, for example through schemes such as R&D tax). These would encourage the upskilling of professionals across all departments and result in a higher probability of success for these manufacturers.

7.5. Conclusion and Key Contributions

This research addressed a shortfall in practical approaches to deal with this transformation affecting the automotive manufacturing industry. It also provided a qualitative tool to evaluate the appropriability position of manufacturers (MARC Model) which allows for an assessment of the particular business model and value proposition in relation to the IP strategy supporting manufacturers to identify risks and opportunities emanating from the implementation of Industry 4.0 technologies across their value chains.

The study also addresses the lack of research providing empirical data for manufacturers to draw upon in order to address challenges faced by this industry. As the study has demonstrated, there is limited understanding of how to protect valuable IP in the context of highly integrated value chains with large amounts of IP embodied in data sets and highly codified models which are not suitable for protection via patents and other traditional forms of IP protection mechanisms.

In addition, this research provides evidence of the risk that unless the relationships in the manufacturing value chains are effectively and strategically coordinated, utilising tools and strategies developed to identify the value appropriation dynamics, manufacturing businesses will simply fail to appropriate an acceptable and sustainable level of value from their innovations, or will withdraw from the relationships and exclude themselves from the digitally connected value chains.

If the manufacturers fail to upskill their workforce and transform their business models and IP strategies, they will continue to generate IP; however, they will be unable to capitalise on the valuable data, know-how, trade secrets and inventions developed in the horizontally integrated value chains.

This in turn, will have a long-term impact on the UK automotive manufacturing industry, which is likely to lose valuable intellectual property and the competitive advantage, as well as the revenue associated with IP, which could be utilised to fund further innovation initiatives. This loss of IP could in turn contribute to the slowing of economic growth in this industry and negatively affect the development of new technologies in the UK automotive manufacturing value chain.

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APPENDICES

Appendix 1: Participant Information Sheet

Appendix 2: Informed Consent Form

Appendix 3: Peer Reviewed Publication 01:

SOARES, M. N.; KAUFFMAN M. E.; SALES, G. M. C. (2019) "Legal Advances in the European Union (Intellectual Property Law and Industry 4.0): Extraterritoriality and Applicability of Comparative Law in Brazil". Revista do Direito. Santa Cruz do Sul, 1 (57), 117-137.

Appendix 4: Peer Reviewed Publication 02:

SOARES, M. N.; KAUFFMAN, M. E. (2018) "Intellectual Property Law in the Fourth Industrial Revolution: Trade Secrets Risks and Opportunities". Revista Juridica. Curitiba, 03 (52), 199-224.

Appendix 5: Peer Reviewed Publication 03:

SOARES, M. N.; KAUFFMAN, M. E. (2018) "Industry 4.0: Horizontal Integration and Intellectual Property Law Strategies in England". Revista Opiniao Juridica (Fortaleza), 16 (23), 268.

Appendix 1 – Participant Information Sheet

Research Title: "Industry 4.0: The new connected value networks, the new business models and the legal challenges and opportunities emanating from the digitalisation of value networks."

PARTICIPANT INFORMATION SHEET

You are being invited to take part in research which explores the phenomenon of Industry 4.0 from a business perspective, viewed through the lenses of a Business Model. This will enable the research to make a contribution to the business model literature, as well as allow the identification of sources of value, how these can be analyse, generated and captured in this new industrial paradigm. Marcos Kauffman, PhD student at Coventry University is undertaking this research. Before you decide to take part it is important you understand why the research is being conducted and what it will involve. Please take time to read the following information carefully.

What is the purpose of the study?
Marcos Kauffman is currently working on a piece of research examining the potential challenges and opportunities emanating from the adoption of Industry 4.0 in order to ensure the sustainable success of businesses on the face of the fourth industrial revolution.

Why have I been chosen?
You are invited to participate in this study because you have been identified as a subject area expert or a practitioner with considerable experience in one or more relevant areas for this research.

Will my taking part in this study be kept confidential and anonymous?
Yes. Information collected about you during the research will be kept strictly confidential and the information and data that you provide in the interview will be made anonymous. Data collected from participants will be referred to by a unique participant number rather than by name to ensure anonymity. If you consent to having the interview discussion recorded, all recordings will be destroyed once they have been transcribed. Transcripts from the research will only be viewed by the researcher and will be stored on a password-protected computer file. Your consent information will be kept separately from your responses in order to mitigate risks in the event of a security breach. All data from the research will be destroyed on or before 31/12/2020.

Do I have to take part?
No – it is entirely up to you. If you do decide to take part, please keep this Information Sheet and complete the informed consent form at the start of the interview, to show that you understand your rights in relation to this research, and are happy to participate. Please note down your participant number (which is on the Consent Form) and provide this if seeking to withdraw from the study later. You are free to withdraw the information you provide by contacting the lead researcher (contact details are provided at the end of this sheet) by 31/12/2017 without giving a reason. A decision to withdraw, or a decision not to take part, will not affect you in any way.

What will happen if I take part?
If you would like to be interviewed as part of the research, you will be asked a number of questions regarding your experiences and the potential risks and opportunities in relation to the implementation of Industry 4.0 and its impact on business models and the legal framework controlling the relationship between businesses. The interview will take place in a safe environment

at a time and place convenient to you. Ideally, we would like to audio record the interview (and will need your explicit consent for this), so any interview location should be in a reasonably quiet area.

What are the benefits of taking part?
By sharing your experiences with us, you will be helping Marcos Kauffman and Coventry University to better understand the potential impact of Industry 4.0 on business models and the legal framework.

What will happen with the results of this study?
The aim of the research project is to identify, explore and propose a method to analyse and address the potential challenges and opportunities emanating from the adoption of industry 4.0 by taking a pro-active approach to the crucial legal elements controlling the relationships in a value network in order to ensure the sustainable success of businesses in this new era. For this reason, I wish to retain the transcripts of all interviews until 31/12/2018 (all other data formats will be destroyed by 31/12/2020, if not before). In terms of the information you provide (for example quotes or key issues used), this would always be made anonymous in any published article, report or presentation.

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Appendix 2 – Informed Consent Form

Participant No.

INFORMED CONSENT FORM

Research title: "Industry 4.0: The impact of horizontal integration on manufacturing business models and intellectual property strategies."

You are invited to take part in this research study for the purpose of collecting data regarding the impact of Industry 4.0 horizontal integration on manufacturing business models and Intellectual Property Strategies.

Before you decide to take part, you must **read the accompanying Participant Information Sheet.**

If you consent to having the interview audio recorded, all recordings will be destroyed once they have been transcribed. Transcripts from the research will only be viewed by the researcher and will be stored in a password protected computer file until they are destroyed (on [31/12/2020]).

Please do not hesitate to ask questions if there is anything that is not clear or if you would like more information about any aspect of this research. It is important that you feel able to take the necessary time to decide whether or not you wish to take part.

Should you require any further information about this research, please contact:

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Appendix 3 - Peer Reviewed Publication 01

Revista do Direito

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AVANÇOS DA COMUNIDADE EUROPÉIA NO DIREITO DE PROPRIEDADE INTELECTUAL E INDÚSTRIA 4.0: EXTRATERRITORIALIDADE E APLICABILIDADE DO DIREITO COMPARADO NO BRASIL

LEGAL ADVANCES IN THE EUROPEAN UNION (INTELLECTUAL PROPERTY LAW AND INDUSTRY 4.0): EXTRATERRITORIALITY AND APPLICABILITY OF COMPARATIVE LAW IN BRAZIL

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Gabriel Mendes de Catunda Sales[1]

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Resumo: O artigo visa fornecer uma avaliação crítica sobre direito intelectual e Indústria 4.0, problematizando como a adoção generalizada de novas tecnologias digitais (Big Data Analytics, Internet of Things, sistemas robóticos, inteligência artificial e etc.) pode afetar a formulação do direito e resultar em novos entendimentos, sobretudo com relação à tutela de direitos de propriedade intelectual. Adota-se a metodologia hipotético-dedutiva a partir de pesquisa bibliográfica e do acórdão da Corte de Apelação do Reino Unido (caso nº B2/2013/1812), sobretudo no sentido de analisar os avanços na Europa e no sistema inglês, que demonstram uma maior velocidade de resposta para novos problemas na proteção de dados, sugerindo-se, ao final, a aplicação do direito comparado no Brasil em situações de omissão legislativa, enquanto não haja legislação específica, com base nos usos e costumes globalizados.

Palavras-chave: Big data. Direito de propriedade intelectual. Indústria 4.0. Internet das Coisas. Sistema legal da União Europeia.

Abstract: This article aims to provide a critical evaluation Industry 4.0 and intellectual property law, questioning how the widespread adoption of new digital technologies (Internet of Things, robotic systems, artificial intelligence, Big Data Analytics, etc.) can affect the formulation of the intellectual property rights and result in new insights, especially regarding the protection of intellectual property. This assay adopts the hypothetical-deductive methodology utilising literature review and the jurisprudence from UK Court of Appeal (case No. B2/2013/1812) in order to analyse the progress in this area in Europe and in the English legal system, both of which are demonstrating a greater speed in the response to new problems in data protection, recommending at the end, the application of comparative law in Brazil in cases of legislative omission, while there is no specific legislation based on globalized customs.

Keywords: Big data. Intellectual Property Law. Industry 4.0. Internet of Things. Europe Union legal System.

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M Kauffman - Revista Do Direito April 2019.pdf

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INTELLECTUAL PROPERTY LAW IN THE FOURTH INDUSTRIAL REVOLUTION: TRADE SECRETS RISKS AND OPPORTUNITIES

DIREITO DE PROPRIEDADE INTELECTUAL NA QUARTA REVOLUÇÃO INDUSTRIAL: SEGREDOS E OPORTUNIDADES DOS SEGREDOS COMERCIAIS

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ABSTRACT

Intellectual Property (IP) is increasingly recognised as a paramount intangible asset influencing the value of companies, as well as their corporate strategies and management. This article focuses on the risks and opportunities associated with the implementation of new technologies on the protection of trade secrets. The study concludes that Intellectual Property Law and Contract Law solutions must be

Appendix 5 - Peer Reviewed Publication 03

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Industry 4.0: Horizontal Integration and Intellectual Property Law Strategies In England

*Marcelo Negri Soares**
*Marcos Kauffman***

ABSTRACT

Intellectual Property (IP) is increasingly recognised as a paramount intangible asset influencing the value of companies, as well as their corporate strategies and management. This paper focuses on the impact of implementing Industry 4.0 (I4.0) on the management of IP in collaborative inter-organisational interconnected networks. Such interconnected networks will allow groups of companies, often competitors and/or customers, to share data and to collaborate in the design, development and manufacture of complex products and/or services, exchanging large amounts of proprietary technical data. Furthermore, this paper explores how companies can benefit from the interconnected network capabilities, whilst protecting them from any risks regarding the vulnerability of IP assets to misappropriation, unauthorized use or leakage. The

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